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Cover picture—*Shown on the cover is the Imperial College of Tropical Agriculture, Trinidad. The College is the subject of an article in this issue.*

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Adaptation and its Relation to Resistance

by **I. D. Farquharson,** *The Shell Petroleum Company.*

The problem of 'resistance' has assumed such importance in the field of agricultural entomology during the last few years that the subject is often discussed as if it were an isolated property peculiar to agricultural pests in relation to chemical control measures. The relationship of resistance to the biological concept of adaptation, which governs the structure of the entire animal and plant kingdoms, is often disregarded. It is perhaps because of this isolation of the problem that various distorted or even erroneous ideas of the underlying principles of resistance are still widely held and propounded. The following article is an attempt to bring the subject of resistance into perspective and to outline some of the inherent difficulties in any study of its mechanism.

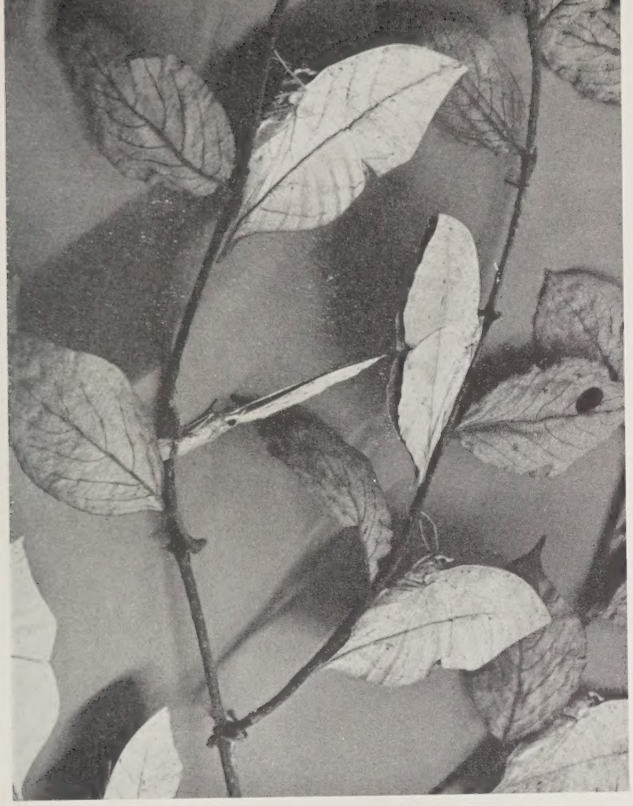
One of the most remarkable features of nature is the adaptation of animals and plants to their environment. Yet such adaptations as the modification of the fore-limbs of birds for flight and the production of coloured blossom by plants to attract pollinating insects are so commonplace as to escape notice; it is only in the more startling cases, such as camouflage and mimicry (2) that the amazing degree to which organisms are adapted to their surroundings is generally appreciated.

Well known are the remarkable stick and leaf insects in which parts of plants are imitated in colour and form with astonishing exactitude, even down to minute details of leaf vein structure. The colour changes, associated with background, to be seen among the molluscs, crustaceans, amphibians and reptiles, of which the chameleon offers the best known example are further outstanding instances of the powers of adaptation.

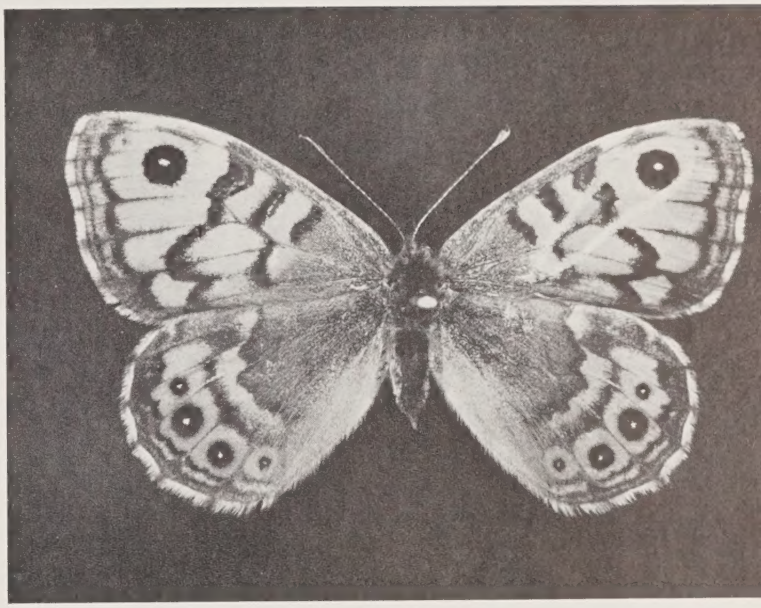
Almost perfect examples of camouflage are presented by the bark geeko and the willow beauty moth which are practically invisible against the bark on which they normally rest. Moreover, there is often an associated adaptation in behaviour. Thus the willow beauty moth will invariably come to rest in such a position that the simulated fissure markings on its wings are in line with the fissures of the bark itself, while the wings at rest are placed close to the bark to eliminate any tell-tale shadow.

Flash colours are a further instance of adaptive coloration. For example, there are certain frogs which, in the crouching position, are perfectly camouflaged. However, the inner sides of the legs are a brilliant vermillion, and when the frog leaps there is a bright flash of colour. The appearance to an approaching predator is of a movement of dazzling colour which completely disappears when the frog comes to rest. Similar effects are to be found in moths in which the inner sides of the wings are brightly coloured, the side uppermost at rest being camouflaged. In flight such moths are conspicuous but they appear to vanish when they alight.

It is usually difficult to establish with certainty that any particular character has adaptive significance, but this is, for example, clearly so in the case of the eyespots at the tips of the wings of many moths and butterflies. Specimens caught, in which the eyespot shows the marks of bird beaks, are evidence of the significance of this adaptation in serving



A group of leaf butterflies (Kallima imachus) *resting on a branch. This butterfly is a native of south-east Asia.*



On this wall butterfly (Parange megera) *can be seen the beak mark of a blackbird (right forewing).*

to attract the attention of preying birds away from the more vulnerable parts of the insect.

A further example of extreme adaptation worthy of note is that of mimicry (2) (3). Offensive insects which are shunned by predators (ants and wasps, for example) or insects that are distasteful to predators because of some noxious substance exuded may be imitated in shape and colour by defenceless insects of the same or an entirely different group. Thus, ants are mimicked independently by certain insects of four distinct orders—a remarkable instance of convergent adaptation. The result of mimicry between distantly connected groups is that the mimic departs markedly from the usual appearance of the group to which it belongs. Even more remarkable, they may depart also in their behaviour: often mimics do not merely look like their models, they also behave like them.

Adaptation, in fact, can be structural, behavioural or physiological. In the cat family, the raising of the legs on to the toes for increased speed, the forward directed eyes for binocular vision and thereby assessment of distance, the sheathed claws and the cutting teeth are all structural adaptations. In the same family, the stalking motion is a behavioural adaptation, while the camouflage patterning and the enzymes to deal with a predominantly meat diet are physiological adaptations to a common end—a carnivorous habit.

Resistance in insects is undoubtedly most frequently an example of physiological adaptation, in which resistant insects are adapted in their body chemistry to survive in the unnatural environment provided by the application of insecticides. However, this does not rule out the possibility of associated structural and behavioural adaptations acting as contributory factors to resistance.

Adaptation, then, is a fundamental and dynamic biological principle, but what is the underlying mechanism by which animals and plants can conform so remarkably to an ever-changing environment?

It is now virtually accepted that adaptation is not a once-and-for-all phenomenon, but a continuous process, itself a product of two factors—variation and natural selection.

Natural selection is the term applied to the process whereby certain organisms are eliminated, either directly or by suppression, over a number of generations, because they are less well adapted to the particular environment in which they occur than others. So the better adapted organisms form an increasing proportion of the population.

The primary requisite for natural selection is a variability of characters on which the selection can act. However, if the selection is to have anything but a temporary effect on the population as a whole, it must be a hereditable variability, in other words, one based on genetic variation.

Genetic variation in a bisexual population is a product of two effects:—

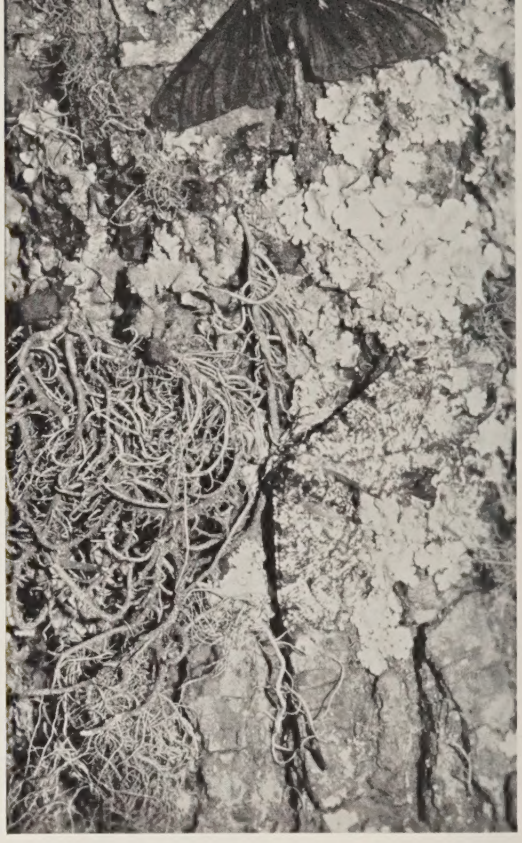
(*a*) The reshuffling of genes to form different genetic combinations, due to the random mating of individuals of different genetic make-up; and

(*b*) The ability of genes to undergo mutation, i.e., a change resulting in change of the governed character.

The first effect is ultimately dependent upon the second,

Cryptic and melanic forms of the peppered moth (Biston betularia); *both forms are shown, left on polluted bark, where one is very obvious and the other less so; and right on lichened bark, where only the melanic form is obvious, the cryptic form being extremely difficult to pick out against the background.*

Photos: British Museum (Natural History)



for different genotypes are themselves dependent initially upon mutations.

In the first place, then, there is an entirely random genetic variability which is only secondarily moulded by natural selection acting on the characters governed by the genes. In this respect, the phenomena of dominance and recessiveness play a large part.

In a bisexual organism identical genes derived from each parent are paired together. If, in such an organism, one of a pair of identical genes (allelomorphs) is a mutant, then normally the mutant will either be dominant to the normal gene, when its effect will be expressed as a particular character, or it will be recessive. In the latter case, its effect will be suppressed by that of the normal gene, until the time when, in future generations, it pairs with a similar mutant—that is until the organism is homozygous.

This concept is important, since most mutations are recessive, and will therefore be maintained in the population as hidden variability, even if highly disadvantageous or lethal in the homozygous state. Its importance lies in the fact that natural selection is itself dynamic, being dependent on the ever-changing nature of the environment. Thus, a character which may be highly disadvantageous in a given environment at any one time, may be advantageous should the environment change or should the population spread to a different environment. In other words, a particular adaptive character, such as resistance, does not occur spontaneously with the change of environment. Rather does the change of environment provide the new set of conditions in which a character previously suppressed may now be at an advantage and be favoured by natural selection. One of the best known examples of this is outlined below.

Industrial Melanism

Industrial melanism (4) in moths is perhaps the most certain visual proof of an evolutionary change with adaptive significance. The peppered moth, *Biston betularia*, is one of about 70 species of moth which are at present in the process of showing a change in population from predominantly light to predominantly dark coloured individuals. It has been shown that this change is correlated with the spread of industrialisation throughout Britain during the last hundred years or so.

The peppered moth exists in three definite forms—the normal cryptically coloured *betularia*, and two melanic forms, the more common of which is the extreme black *carbonaria*. All three forms are extensively preyed upon by birds. In unpolluted atmospheric conditions the cryptic form is at a considerable advantage over the melanic forms in that its colour provides a perfect camouflage against the heavily lichened bark of trees on which the moth normally rests. Under these conditions, the melanic forms, although dominant, are maintained only by recurrent mutation, and are rapidly eliminated because they are conspicuous to birds. In industrial areas, where the atmosphere is heavily polluted, lichens cannot exist and the bark of trees in these areas is darkened with soot. Under these conditions, it is the pale coloured typical form which is conspicuous and is eliminated. Records kept since the last century have shown the steady increase, correlated with the intensity of industrialisation, of the melanic form

of the peppered moth since the time when these were rare.

Visual proof of selection was obtained when the various forms were exposed to the attacks of birds in an experimental aviary where their selective elimination on unmatched backgrounds was first demonstrated. Corresponding work was carried out in a wood near Birmingham, where the *carbonaria* form represents about 87 per cent. of the population. A large number of cryptic and melanic moths, marked for identification on the underside of the wing, were released and recaptured at the end of the day, when the relative survival rates were assessed. A similar experiment was undertaken in a heavily lichened and pollution-free wood in rural Dorset, where *carbonaria* occurs only at a very low frequency. In each case, the more conspicuous of the two forms was deficient in numbers among the recaptured moths. Observations showed that birds were responsible for their elimination, both in polluted and unpolluted countryside, and that this took place selectively and in an order which varied according to the camouflage efficiency of each moth in relation to its background.

Genetics of Resistance

From the above example, it can be seen that a mutant form may remain suppressed by selection over a long period in an environment in which it is at a disadvantage, but it may be at an advantage and increase throughout the population if the environment changes. Thus, mutation is advantageous and even necessary to the species as a whole in securing its survival under conditions of changing environment. Moreover, the more intense the environmental change, the more intense will be the selection for any mutant having an advantage in the new environment.

The application of this concept to the problem of resistance is obvious: resistance is not an increasing tolerance of individual insects brought about by the application of insecticides, but is the result of the increase in numbers of a strain better adapted to an artificial change in environment. Presumably the resistant strain was already present in the population, and under normal conditions, because it occurred only at low frequency, it was at some disadvantage compared with the non-resistant strain. On the sudden and extreme change of environment, provided by application of insecticide, it is now the normal strain which is selected against. It is therefore misleading to speak of insects 'building up resistance' to insecticides.

The fact that a resistant strain is probably at a disadvantage in some other respect compared with the non-resistant strain before the insecticide has been applied brings to light a further point. A single gene may be responsible for several characters, and it is not necessarily the most obvious which is under the action of selection. Thus, in the case of industrial melanism, it has become evident that there are physiological and behavioural differences between the melanic and cryptic forms. There is, for instance, evidence that there is a differential survival rate between larvae of the different forms when feeding on polluted foliage, a larger proportion of the larvae of melanic forms surviving under these conditions. The fact that a single gene may govern several factors explains the fact that some characters appear to have no adaptive significance. It is probable that these non-adaptive characters, although perhaps most obvious to the human eye, are in fact secondary expressions of a gene governing some other, maybe physiological or behavioural, character which is under the action of selection (1).

Gene Effects

The study of the genetics of resistance may be further complicated by the fact that quite distinct genes may have similar effects. Thus, in the rabbit, the condition, 'rex' (in which the fur is without its normal stiff guard hairs), can be produced by any of three distinct genes. On the other hand, the same gene may have different effects in different individuals, dependent upon the other genes present in the individual. Again, some genes are without effect unless they occur with certain others. In mice, there is a gene which results in a white spotted patterning of the fur. Another gene has no action alone, but when it occurs with the gene for white spotting, the result is an extension of the spots to form large white patches. Many genes are cumulative in effect, and it is these which are responsible for continuous variation (human height, for example) although continuous variation itself may be secondarily modified by environment.

Yet other genes produce their effect only in the particular environment provided by one or other of the sexes, that is, 'sex limited' or 'sex controlled' genes. An example is one form of baldness in the human, the gene acting whenever it occurs in the male, but only having an effect in the female when it is paired with a similar gene. Genes, in fact, co-operate to produce what is known as a gene complex, and the alteration of a particular gene by mutation may have profound effects on the working of the other genes of the complex.

Resistance in any one resistant strain, then, is not necessarily due to a single mutant gene acting alone, nor is there necessarily only a single character involved in resistance. Moreover, the underlying mechanism in different strains is not necessarily the same.

It will be obvious from the foregoing that the problem of the mechanism of resistance is by no means a simple one: its solution for one particular species does not provide a solution for all resistant species. Resistance is an adaptive character and, as such, should not be regarded as differing in principle from the adaptation of all organisms to the natural environment (5) (6). The underlying factors, in all their complexity, governing adaptation as a whole are no less likely to be found to apply to the phenomenon of resistance.

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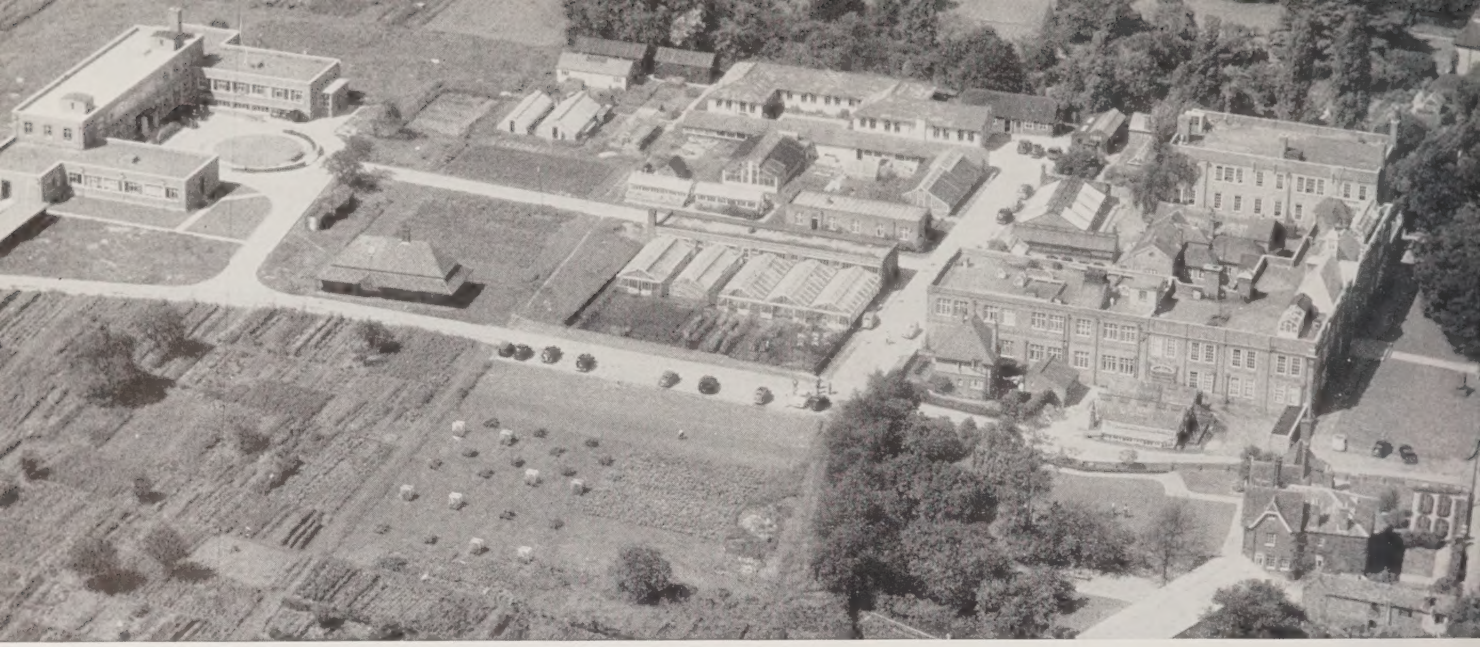

AGRICULTURAL RESEARCH STATIONS – 1 **ROTHAMSTE**

by **F. C. Bawden,** F.R.S.

This article on Rothamsted—the oldest and probably the most famous agricultural research station in the world—is the first in a series on agricultural research stations of international importance which will be published in Span *from time to time. The author was appointed Director of Rothamsted last year, having previously been a deputy director since 1950.*

The Rothamsted Experimental Station dates its foundation from 1843, when John Bennet Lawes began his long and fruitful collaboration with J. H. Gilbert and the experiment on Broadbalk field, now carrying its 116th consecutive wheat crop, was laid down. Lawes, though, had been experimenting for some years before this. He came down from Oxford to take over his estate in 1834 without a degree but with something more useful, and certainly much more unusual for that time, an interest in chemistry.

Lawes immediately equipped a room in his Manor House as a laboratory, and for a time satisfied his interest by seeking the active principles in such drug plants as poppies, belladonna and hemlock, which he grew on the Home Farm. However, his practical bent soon led to other projects, such as trying to devise new processes to make calomel and corrosive sublimate. Those failed, but they gave him experience that proved useful when his attention turned to making agricultural chemicals, which happened as the result of a neighbour telling him that bones were an invaluable manure for turnips on some fields though useless on others.

Pondering this, for he had spent money on bones to little purpose on his own farm, he treated bones, or rather charred bones for which he had been asked to find a use, with sulphuric acid, which he had for making chlorine, and produced the soluble phosphatic fertiliser he called 'Super Phosphate of Lime'. Tests in pots and small plots gave striking growth responses, particularly with turnips, and after larger field trials in 1841 confirmed its value he patented his process for decomposing 'phosphoritic' substances with sulphuric acids and started a fertiliser business. The first advertisement for his products appeared in the *Gardener's Chronicle* for July 1, 1843.

The First 50 Years

With Gilbert's appointment, a series of systematic field experiments was begun to establish the nutritional requirements of various crops, starting with wheat and turnips to which were soon added barley, clover and meadow hay. In some experiments, one crop was grown continuously on the same land, with the different plots each receiving its own treatment repeated year after year. Others conformed more to agricultural practice, with different crops grown in rotation. The crops, soils, manures and rain and drainage water were analysed to get as good a balance sheet as possible, of what was added to the soil, and of its fate, whether it remained there, was taken off in the crop or lost in the drainage.

The same general pattern of treatments was followed in all the experiments: no manure; nitrogen only; minerals only; nitrogen and minerals; farmyard manure. This pattern was in part dictated by a controversy with Liebig, who maintained that plants could get all the nitrogen they needed from the ammonia in the air. Lawes and Gilbert

The first Rothamsted laboratory, a converted barn which was used until about 1855.

Photo : Rothamsted.

Modern Rothamsted. Two additional blocks of glasshouses have been built since this photograph was taken in 1956.

EXPERIMENTAL STATION

challenged this and their experiments soon established beyond doubt that atmospheric supplies were wholly inadequate. Some of these experiments still continue, vividly demonstrating the effects of long-term differences in manuring and providing a series of soils unique in the length of their known history and in the information they carry about the processes of building up and exhausting plant nutrients.

Although the work for which Lawes and Gilbert are best known was on the manuring of crops, they studied other subjects as diverse as the purification of sewage, a comparision of white with wholemeal flour, the effect of malting on the feeding value of barley, and the advantages and disadvantages of ensiling compared with hay making. Their animal-feeding experiments were especially notable, for they established the value of different constituents of the food-stuffs, showed how the composition of animals changes during growth and fattening, and destroyed the belief that animal fat came only from vegetable fat.

For some years the chemical work was done in a barn made to serve as a laboratory, but the practical value of Lawes' work for agriculture soon became appreciated and, as a result of a testimonial fund subscribed by grateful farmers, a new laboratory was built in 1855; this remained in use until 1912, when it was replaced by the present main building. In 1877 the scientific staff increased by 50 per cent. on the appointment of R. Warington, who introduced agriculturalists to the importance of soil microbes by showing that the change of ammonia to nitrate in the soil depends on the activities of micro-organisms.

At this time Lawes played a part in starting an experimental farm for the Royal Agricultural Society of England on the Duke of Bedford's estate at Woburn, where experiments made on the heavy land at Rothamsted could be duplicated on light land. This action has had lasting effects, for after the Society gave up the farm it was taken over by Rothamsted in 1926 and is particularly useful for experiments on market-garden and other crops for which the soil at Harpenden is unsuitable.

The Second 50 Years

Lawes died in 1900 and Gilbert in 1901, but the station got the new inspiration it needed when A. D. Hall was appointed director in 1902. He brought with him from Wye College, as soil chemist, E. J. Russell, who was director from 1912 to 1943, when he was succeeded by W. G. Ogg, who retired in 1958.

Under Hall and Russell the activities of the station grew and widened from the mainly chemical work of the nineteenth century. Before their ideas could be developed, however, money was needed. Until 1904, when the Society for Extending the Rothamsted Experiments was instituted, the work was paid for wholly by Lawes, at first directly and from 1889 from the fund with which he endowed the Lawes Agricultural Trust, the committee of which forms the governing body of the station. Public money first came in 1911, since when government grants have been made annually and most of the work is now financed by grants from the Agricultural Research Council.

With increasing funds, the staff also increased and departments of Botany, Soil Microbiology and Physics were separated from the original Chemistry Department in 1914. The aims and achievements during this period of development are described in the early editions of Russell's now classic book, *Soil Conditions and Plant Growth*. Soon after the end of the first world war, departments of Entomology, Mycology, Insecticides and Fungicides, and Statistics were started, and a few years later the study of bees and of plant viruses and virus diseases was added to the station's activities. There was little further expansion in the 1930s, but with the Second World War most departments increased in size and new ones were formed for Pedology (1945), Biochemistry (1947) and Nematology (1947). In 1947, Rothamsted became the headquarters of the Soil Survey of England and Wales. From 28 in 1912, the total of staff increased to 140 in 1943 and to 470 in 1958. In addition, the Station houses the Commonwealth Bureau of Soils, and also accommodates many visiting research workers, mostly from overseas.

The experimental fields for long amounted to only about 50 acres, but the Home Farm of 250 acres was rented in 1911 and two years later the first farm buildings specifically for the field experiments were put up on the site of the present range. In 1934, the Manor House, Home Farm and various other parts of the estate were bought by the Lawes Agricultural Trust from money raised by public subscription. Some additional land has been acquired since, and the area owned now totals 600 acres, of which about half are suitable for experiments. There are annually now some 3,000 plots at Rothamsted, many others at Woburn, at the Dunholme Field Station, Lincoln, the centre for work on

sugar-beet problems financed by the Sugar Beet Research and Education Committee, and, so that results can be related to different soil types and climates, some experiments are made on other farms in various parts of the country. Also, in nurseries of the Forestry Commission, the nutrient requirements of conifer seedlings and transplants are studied—a problem of practical importance that also provides an opportunity to study soils of lower fertility than those usual in agriculture or horticulture.

The famous Broadbalk field, showing the 17 strip plots, each of which has received its own treatment annually since 1843; the far right-hand plot receives 14 tons of farmyard manure each year and the one immediately next to it nothing. The white area is the block under fallow (one-fifth has been fallowed each year since 1925). A modern experiment with 64 plots can be seen in the top left-hand corner of the picture.

Current Work

The preceding paragraph shows that field experiments still constitute a large part of the station's activities, and this is inevitable. Not only must they be the final test of principles or practices suggested by investigations in the laboratory or glasshouse, but problems posed by field crops both stimulate these investigations and keep them relevant to agricultural needs.

The type, pattern and subjects of the modern field experiments, however, have moved far from those of the pioneering times. For example, had the size of plot remained unchanged since the time when Broadbalk was laid down, the present programme at Rothamsted alone would require 1,500 acres, and one of the current experiments, which compares continuous arable cropping with rotations containing three-year leys, would occupy more than the total experimental area in use until 1912. But the experimental designs developed in the Statistics Department do more than use smaller plots: they measure smaller differences than previously, assess the validity of results, allow more treatments to be compared in one experiment, and measure the interactions between treatments as well as their main effects. The old experiments with a single large plot per treatment magnificently demonstrate main effects, but the information they give per unit of land or of labour is wholly inadequate for modern conditions.

Many of the field experiments are still concerned with problems arising out of the use of manures and fertilisers on different kinds of crop. These compare the values of different kinds of organic and inorganic manures, test different methods of application, seek the optimum rate and date to apply them, and study the accumulated residual effects in addition to the immediate responses of the crops to which they are applied.

But the field experiments now extend to a wide variety of problems other than crop nutrition. They include the effects of different types of cultivations and rotations on soil structure, tilth, weed populations and crop yields, the reponses to irrigation, and, increasingly, they are concerned with pests and diseases. Some test possible control practices, not only by the use of insecticides and fungicides, but also by varying cultural practices, sowing dates and rotations. Recent successes include the control of black bean aphids by one well-timed application of a systemic insecticide; checking the spread of potato leaf roll and sugar beet yellows viruses by persistent insecticides; protecting brassica seedlings and sugar-beet stecklings from virus diseases by surrounding the beds with cereals; and increasing the yields of wheat when eyespot (lodging) and some other troubles are controlled by interpolating crops such as beans and potatoes between cereals.

Other field trials assess the economic importance of individual pests and diseases, or are epidemiological studies to find their sources and define the conditions that make them develop dangerously, to help devise preventive measures or to forecast the occasions when control measures need to be used so that their application can be properly timed.

To list the problems being studied by 200 graduates would be tedious even if it were possible in the scope of a short article; they range from X-ray studies of clay particles, through variations in the nitrogen-fixing abilities of strains of the clover nodule bacteria, the movement of nematodes in soil, the botanical factors that determine the differences in yield between different varieties of plants, to the nature of viruses and the various ways these are transmitted by different arthropods. Almost every problem relevant to the growth of healthy crops, except the breeding of new varieties, is studied.

Soil conditions and plant growth no longer adequately indicates the range of current activities, which are perhaps

best outlined simply by listing the departments—Bees, Biochemistry, Botany, Chemistry, Entomology, Insecticides and Fungicides, Nematology, Pedology, Plant Pathology, Soil Microbiology and Statistics. However, even this does not give the whole picture. It fails to show the collaboration between workers in different departments—of physicists with botanists and plant pathologists to study the influence of weather on crop growth and disease outbreaks; of biochemists with nematologists to find the nature of the eelworm 'hatching factor' exuded by plant roots; of members of the Bees and Insecticide Departments to find how current sprays affect pollinating insects; or the aid given by statisticians to workers in most other departments in the design and analysis of their experiments.

Nor do the names of the departments fully cover their activities. For example, the Entomology Department studies more than insect pests; the work extends to other kinds of pests such as slugs, to parasites and predators of pests, and to animals such as earthworms that affect soil structure and may be beneficial to crops. The Biochemistry Department's name, too, does not suggest that one of its major activities is to produce direct from leaves proteins suitable for human consumption. Again, the Statistics Department does more than work on Rothamsted's problems—it conducts surveys for the Ministry of Agriculture, Fisheries & Food on fertiliser practice and other subjects such as disease and fertility in farm animals, and provides a statistical service for the National Agricultural Advisory Service and for other research stations in the United Kingdom and parts of the Commonwealth. The work of most departments combines long-term projects to establish principles with short-term ones on problems of immediate practical interest.

The wide range of subjects studied calls for an equally wide range of techniques and apparatus. All modern methods of analysis are used, and radio-active isotopes are employed where they can give results, as in work with phosphatic fertilisers, not otherwise readily obtained. Some of the special pieces of apparatus, such as the Potter tower for assaying insecticides, the Hirst automatic spore trap, and a suction trap for insects, were developed at Rothamsted, but many others, as varied in their purpose as an electronic computer and an electron microscope, are applied in the ever-growing need to get results more quickly and to measure smaller objects and smaller differences so that the many and varied factors that limit the productivity of crops may be better understood.

Nematode Pests of Perennial Crops

by **C. W. McBeth**, *Shell Development Company, USA*

The author has been nematologist at Modesto Agricultural Laboratory, California, since 1945; the previous nine years he spent working on nematological problems with the US Department of Agriculture. His article, which includes a valuable bibliography, is based almost entirely on work carried out in the USA, where knowledge of plant parasitic nematodes and their control is probably more advanced than anywhere else in the world.

Plant parasitic nematodes are found wherever plants are grown, and it is believed that every species of plant is a host of at least one nematode species. In perennial cultivated crops the problem of nematode infestation is especially serious, as several years are required for such crops to come into production; in many cases they never reach full production because of damage caused by nematodes.

As a rule, very little trouble results in the first planting of a crop even though the planting stock may be lightly infected: the most serious damage results in replanting in infested soil with the same crop. If the population is high, the plants may not become established, or, even worse, they may make feeble growth for two or three years and then decline. These symptoms are often attributed to poor soil, worn out soil, or toxic residues.

There are instances of industries being almost eliminated through damage by nematodes. In the United States there are areas in which the sugar beet industry has been almost completely wiped out by infestation with the sugar beet nematode. In Georgia, the peach industry has gradually moved from the sandy coastal plain area to the heavier soils of the northern part of the state where the root knot nematode is less of a problem. This is only a temporary reprieve, however, as the problem is becoming serious in parts of that area also.

During the past 20-30 years a serious replant problem has developed in many areas of the United States with citrus, walnut, peach, grape and olive. In Hawaii, all pineapple land must be fumigated before it can be successfully replanted. Some of the newer agricultural areas, including parts of Africa, are also experiencing serious replant problems on such crops as citrus, peach, grape, banana, pineapple and sugar cane. Apparently this problem is universal, and in many cases it is associated with high populations of one or more nematode species.

Not all replant problems can be traced to nematodes: in some instances other factors such as fungi, bacteria, virus, insects, poor drainage, are even more devastating than nematodes. In fact, it is becoming generally believed that a combination of these factors may be operating in many cases. There have been a number of examples of nematode-fungus complexes associated with annual crops, such as root knot and *Fusarium* on cotton and tobacco. Anything that upsets one factor within the complex may be sufficient to alleviate the trouble. In this article, however, only plant parasitic nematodes will be considered.

In general, the nematode pests affecting perennial plants do not respect geographical borders: in other words, the same nematode species are usually found wherever a particular plant is grown. The main reason for this is that there has been a free exchange of plant material over the world during the past several generations. Even now, with strict border inspection by some countries, it is not possible to prevent the introduction of nematodes because of their small size and the lack of diagnostic symptoms of an infection. Furthermore, specimens can be introduced in soil and plant residues surrounding the roots of non-host plants—making detection almost impossible. Some of the more serious nematode pests of a few economically important crops are set out below.

CROPS AND ASSOCIATED NEMATODES

Citrus

The citrus nematode, *Tylenchulus semipenetrans* Cobb, 1913, is without doubt the most common nematode pest of citrus; it is found wherever citrus is grown and the damage it causes is generally referred to as 'slow decline'. Some workers believe this nematode to be unimportant because it is found universally on practically all trees in all degrees of vigour.

As this pest has very few hosts other than citrus, the chances are that it does not exist in virgin soil, or cultivated soil that has not previously grown citrus. Consequently, either the plants become infected after planting, by irrigation water, tools, etc., or they are infected in the nursery and introduced in the planting stock. In either case the population would probably be quite low at the beginning and many years would be required to build up populations

sufficiently high to cause severe decline. In fact, if other growing conditions are near ideal, an introduced population may never catch up with the original planting. The true pathogenicity of this pest can be demonstrated, however, by replanting young citrus trees in old infected citrus soil; it can also be demonstrated that old unproductive soil can be rejuvenated by removing the citrus nematode and that virgin soil can be made unfavourable to citrus by adding citrus nematode.

Although not so widespread, the burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949, is believed to be a most important pest of citrus in Florida. The damage caused by this parasite is known as 'spreading decline'. Evidently, this nematode does not require high populations to cause severe decline, as is the case with citrus nematode, in fact, the evidence indicates that a small locus of infection can become established in just one tree and gradually spread throughout an entire planting. This pest does not appear to be so devastating on new plantings as the citrus nematode, since symptoms are not reported as being apparent for four to five years after replanting, while damage from citrus nematode usually shows up immediately.

There are other nematodes which are found in and around the roots of unhealthy citrus trees, such as lesion nematode, *Pratylenchus sp.*; sting nematode, *Belonolaimus gracilis* Steiner, 1949; and stubby root, *Trichodorus sp.*, but little is known concerning the pathogenicity of these nematodes to citrus.

Peach

The root knot nematodes, *Meloidogyne spp.*, are the most well-known and serious pest of peach, especially in tropical and sub-tropical areas. In cooler climates such as northern United States and Canada, the lesion type nematode, *Pratylenchus penetrans* (Cobb, 1917), is more serious. Other types known as ectoparasites, or surface feeders, are also found in the root zone of unhealthy trees although their importance to peach is not known.

As has been pointed out above, the peach industry of Georgia was driven from the south to the north because of severe injury by the root knot nematode. There are at least two root knot species that are serious pests of peach, *Meloidogyne incognita acrita* (Chitwood, 1949), and *M. javanica javanica* (Treub, 1885) Chitwood, 1949. Certain rootstocks are highly resistant or immune to *M. incognita incognita* (Kofoid and White, 1919) Chitwood, 1949, but not to *M. javanica javanica*. These stocks are discussed under the section devoted to control measures.

Walnut

The most serious nematode pest of walnut is lesion nematode, *Pratylenchus vulnus* Allen and Jensen, 1951. In California many old plantings are declining and becoming unproductive because of this pest. It is also very difficult to establish a new planting in old walnut soil. Two rootstocks, Paradox (hybrid) and Chinese wing nut, *Pterocarya stenoptera*, show some promise although neither is entirely immune.

Although root knot, *Meloidogyne sp.*, is occasionally found infecting walnut, it is of minor importance. *Cacopaurus epacris* Allen and Jensen, 1950, has been reported to cause decline of walnut.

Cherry

The lesion nematode, *Pratylenchus penetrans* (Cobb, 1917), appears to be the most destructive nematode pest of cherry, although the dagger nematode, *Xiphinema americanum* Cobb, 1913, is also believed to be important. The main problem in cherry, as in other tree crops, is the establishment of new plantings in old cherry soil.

Grape

Grapes are very seriously injured by the root knot nematode, *Meloidogyne spp.*, and in many areas the yield is reduced from one-half to one-third of normal by a heavy root knot infection. Control of root knot nematode on grapes has resulted in better quality grapes due to increased foliage. Other nematodes are also believed to be important, such as lesion, *Pratylenchus vulnus*; dagger, *Xiphinema sp.*; and stubby root, *Trichodorus sp.*, although nothing definite is known.

Several rootstocks, including 1613, Dog Ridge, and Salt Creek, are highly resistant to root knot but do not produce quality equal to that obtained from the common rootstocks.

Recent work by HEWETT and RASKI has proved *Xiphinema index* to be the vector of fanleaf disease of grape. This is the first recorded instance of a virus being transmitted by a nematode. Besides occurring in the USA fanleaf virus is also a problem in the wine producing vineyards of France, and it is known that a species of *Xiphinema* is present in many French vineyard soils.

Fig

Like peach and grape, fig is found most commonly infected with root knot nematode, *Meloidogyne spp.* Other possible important parasites are lesion, *Pratylenchus vulnus*; pin, *Paratylenchus hamatus* Thorne and Allen, 1950; and dagger, *Xiphinema index* Thorne and Allen, 1950. There are no resistant fig rootstocks commercially available at the present time.

Banana

There are two main nematode pests of banana and several others that are questionable. The burrowing nematode, *Radopholus similis*, and root knot, *Meloidogyne spp.*, are most commonly associated with unhealthy plants. A lesion nematode, *Pratylenchus coffeae* (Zimmerman, 1898), and a spiral nematode, *Rotylenchus sp.*, may also be important.

Strawberry

The three known nematode pests of strawberry are root knot, *Meloidogyne hapla* Chitwood, 1949, lesion; *Pratylenchus penetrans;* and sting, *Belonolaimus gracilis*. The productive life of strawberries can be extended by one to two years in some areas by controlling these forms.

Pineapple

The root knot nematode, *Meloidogyne javanica javanica*,

This photograph of banana trees in French Guinea shows the effect of soil fumigation with Nemagon. The trees on the right were treated at the rate of 3-5 gal. (Imperial) per acre; the tree on the left was not treated and is stunted as a result of nematode infestation.

Seedling cherries attacked by Pratylenchus penetrans: *those in the foreground are growing in soil fumigated with D-D at 20 gal. (US) per acre about three weeks before planting. Contrast them with the seedlings growing in untreated soil.*

is probably the most important nematode pest of pineapple, although lesion nematode, *Pratylenchus brachyurus* (Godfrey, 1929) Goodey, 1951; pin nematode, *Paratylenchus sp.*; and kidney shaped nematode, *Rotylenchulus reniformis* Linford and Oliveira, 1940, are also known to be taking their toll. Wherever pineapple has been repeatedly grown, these pests have become a limiting factor in production, and, as has already been pointed out, in Hawaii, all pineapple land is fumigated before being replanted.

There are many other perennial plants that are known to be severely affected by certain plant parasitic nematodes, but those listed above are some of the more common and important crops, and serve to illustrate the importance of these pests to long-term crops. Deciduous and tropical fruits, tea, coffee and cacao, spices, meadow grasses and legumes, bulbs and other ornamentals—in fact, all common perennial crops—are more or less regularly subject to attack by a variety of nematodes. In addition a number of perennial crops have specific nematodes associated with them: red ring of coconut caused by *Aphelenchoides cocophilus* (Cobb, 1919) Goodey, 1933; the hop nematode, *Heterodera humuli* Filipjev, 1934; and mint nematode, *Longidorus sylphus* Thorne, 1939.

CONTROL

Because perennial plants grow over a period of many years, it is difficult to protect them from nematode attack and even more difficult to prevent damage after they have become attacked. There are many ways in which this problem can be approached, although there are no easy, cheap foolproof methods yet devised. Let us consider some of the most effective.

Clean Planting Stock

The surest method of distributing nematodes to uninfected areas is through nursery or planting stock. Until recently, even though the problem was well known, very little attempt was made to produce nematode-free stock, except for certain annuals (tobacco, tomato and celery, for example). The classic example of a nematode being distributed world-wide in planting stock is the citrus nematode, *Tylenchulus semipenetrans.*

All planting stock should be grown in virgin or fumigated soil.

Rotation

It is difficult to rotate perennial crops because the growing interval or life span is so long (two to four years for strawberries and pineapple, and up to 60 years for grapes, walnuts, citrus, etc.), but the interval between removing an old planting and replanting can be extended over several years, and annual crops immune to the parasitic nematode involved can be grown. Nevertheless, this is often difficult, as frequently more than one nematode species is involved, making it difficult to find an economic crop immune to all species. As an added complication, the roots of some plants, such as grape and citrus, can remain in the soil for many years after the plant has been removed in apparently very good condition, and nematodes have sometimes

been found to be still living on these residual roots. This, of course, defeats the purpose of a rotation. A rotation of perennial crops, such as citrus to walnut, or grape to peach, is effective, especially if they are not hosts of the same nematode.

Rootstocks

Resistant and immune rootstocks provide very effective means of controlling root pests of perennial plants. The main problem appears to be in finding rootstocks that are immune to more than one nematode species. Several promising stocks have been developed for use on peach which are immune to most—but not all—species of root knot nematode and have a limited use. The same is true for grape and walnut: rootstocks highly resistant to certain of the pests are available but not entirely satisfactory.

Cover Crops

For nematode control, annual cover crops, immune to pests affecting a perennial crop, have been demonstrated to be beneficial, but the main problem is to find a cover crop that is immune to all nematode pests involved. Immune cover crops do not necessarily reduce the population in the original root zone of the plant, but they reduce the population in the area surrounding the root zone, resulting in uninfested soil for the new roots to spread into. If a susceptible cover crop is grown the nematode population is kept high in the surrounding soil.

Clean Cultivation

Most plant parasitic nematodes must have suitable plant roots to feed on, otherwise they will starve within one or two growing seasons; this does not apply to the majority of cyst forming nematodes (which in any case are not common pests of perennial plants, with the exception of the hop nematode, *Heterodera humuli*).

In areas of low rainfall, control by clean cultivation can be assisted by turning the soil several times during the dry, hot time of the year. This method has given a high degree of control of root knot nematode in one season; the main objection to it is that no return is received from the land during the period and the land must be worked several times to control weed hosts.

Where nematodes are a problem, clean cultivation in orchards and vineyards is desirable unless an immune cover crop is available.

Chemical Control

The discovery of the nematocidal value of D-D Soil Fumigant (dichloropropene-dichloropropane mixture) by CARTER, in 1943 and of EDB (ethylene dibromide) by CHRISTIE, in 1945, introduced for the first time a practical, economic method of controlling plant parasitic nematodes on a field scale. Before this discovery, the only nematocides known were chloropicrin and carbon disulphide—and neither was economic for widespread use.

At present, land to be planted to pineapple in Hawaii is first treated with D-D at 40 gal. (US) per acre. In the main citrus growing areas of the United States, soil to be

The grape vines on the left of this picture are nematode-infested and have not been treated. Those on the right were treated with Nemagon at 5 gal. (US) per acre in the year before the photograph was taken.

A walnut tree infested with lesion nematode (Pratylenchus vulnus.) *Inset, a piece of walnut tree root damaged by* P. vulnus.

replanted is treated with D-D and strawberry, peach, grape, and walnut soils are also being pre-plant treated where nematodes are a problem.

Because D-D is toxic to the roots of plants, a waiting period of from three weeks to six months is necessary between treating and planting. The interval is dependent on the dosage used and also to some extent on the soil type.

Where tree soils are being treated, it has been found that, for best results, at least one year should elapse between the time the old trees are pulled and the fumigant is applied; this allows the old roots to break down and the eggs and larvae to be released. As mentioned previously, the roots of citrus and grape may remain in an apparently living condition in the soil for several years, which may reduce the value of delaying fumigation for more than one year after the plants are pulled. In Florida, where burrowing nematode of citrus is a problem, treatment immediately after the trees are pulled, in order to prevent further spread of the pest, is recommended.

A new product, Nemagon Soil Fumigant (1,2-dibromo-3-chloropropane) has recently been introduced and is becoming increasingly widely used; this material is unique in that it can be used as a post-plant as well as a pre-plant treatment for many crops, in fact it is the only commercial material at present that shows promise of controlling nematodes on living plants. Grape, citrus, strawberry, olive, peach, walnut, fig, banana, pineapple and many ornamentals have been successfully treated with Nemagon. The indications are that it can best be used to keep healthy plants healthy rather than for attempting to rejuvenate plants in an advanced stage of decline.

Nemagon Soil Fumigant is available as a liquid for injection, as an emulsifiable concentrate for application as a drench, and impregnated on a solid carrier for application by fertiliser distributor. The granular material should be used in the same manner as the liquid. It should be injected six to eight inches deep and sealed with a drag or roller; a reduction of 50 per cent. activity can be expected if the material is merely spread on the soil surface and disced or 'rototilled' in.

In conclusion, one can say that the prospects for controlling nematodes by chemical means on perennial, as well as on annual crops, are very encouraging, though there still remains much work to be done, both in the USA and in other countries where nematodes are now becoming recognised as a serious menace to crop production.

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Higher Education in Agriculture

A SYMPOSIUM OF SEVEN PAPERS

Introduced by

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Amongst university disciplines agriculture is still somewhat of a newcomer and the approach to its study and teaching is encouragingly dynamic. A very definite pattern, however, emerges of the way in which universities, by and large, have evolved, and are actively evolving, their handling of the discipline, basing it firmly on a fundamental warp of the natural sciences into which is woven the weft of the economic and social sciences. The end in view is to produce a full appreciation of the husbandries and technologies together with a proper understanding of the farm and the agricultural industry as economic entities.

The pattern varies somewhat from country to country largely according to the background of secondary school education and to the nature and function of the university as a whole. Much discussion turns on the amount of specialisation which can or should be introduced at the level of the first degree; some hold that agriculture is already too wide and diverse a subject to be studied comprehensively, whereas others claim that specialisation is scarcely admissible until the post-graduate phase. There is, however, much general agreement concerning the general approach, the great importance of the post-graduate study of the subject and the essentiality of the closest possible association of research work with those departments concerned with the teaching of the subject, without which the study lacks the fundamental approach which is so essential to a university discipline.

In the last 12 years, since the war, one or two very general trends may be observed. The standards demanded in the basic natural sciences have increased, the importance of the economic and social sciences has grown, and the subject of farm management is now dealt with objectively as opposed to by rule of thumb. Furthermore, there would seem to be a growing agreement that at least two types of degree are probably required, the one a general degree primarily to serve the needs of those who intend to become executives, and the other an honours degree involving a more fundamental approach to the subject for those who intend to follow a more academic career in teaching, research or extension work.

Sometimes those who are concerned, in their various spheres, with employing graduates in agriculture are critical of the university approach, regarding it as too out of touch with the needs of industry and management, insufficiently specialised and, in general, too 'academic'. It must be remembered, however, that the universities' job is not to turn out technicians but young people intellectually disciplined to serve the community in very varying fields in agriculture. If the subject is to be admitted to the university it is essential that it be dealt with, in parallel to other university disciplines, after the way of a university.

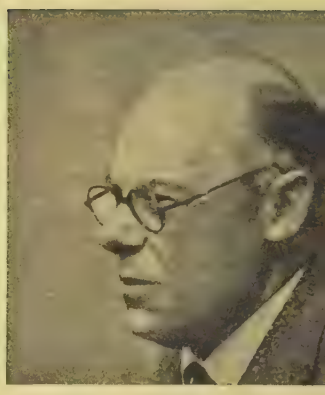
In the end, the real test of the contribution which the universities make to higher education in agriculture depends upon the quality—not the quantity—of the human material produced. This depends almost entirely upon two very closely related problems: the high standing and wisdom of the teachers and the potential ability of the students admitted to faculties of agriculture. It has often been remarked that an inspiring teacher transcends the worst of syllabuses and the value of the most forward looking and enlightened syllabus can be negatived by the unimaginative and pedestrian don.

The contribution to be made by higher agricultural education to the industries and peoples it serves will inevitably be measured more in terms of human qualities and abilities than by regulations and syllabuses. The developments to be remarked upon in the most interesting brief papers which follow are full of encouragement; the battle of the last fifty years, during which agriculture has fought for full university recognition, has been won. It now only remains to hope that to its service will be attracted the high level of ability of teachers, research workers and students which the farming industry throughout the world demands if it is to realise its full potentials and not only keep the people fed but provide a full life for all those who produce the world's food.

Higher Agricultural Education in the U.S.A.

by **A. N. Duckham,** C.B.E., *Professor of Agriculture, University of Reading.*

The author *acquired his extensive knowledge of agricultural education in the USA during his service as Agricultural Attaché at the British Embassy in Washington, from 1945 to 1950.*
Educated at Oundle and Clare College, Cambridge, Professor Duckham was engaged from 1927 to 1939 in animal husbandry research and administration. During the war he was Director of Supply Plans and Agricultural Adviser to the Ministry of Food. On his return to England from the USA in 1950 he became Assistant Secretary at the Ministry of Agriculture, where he remained until 1954. The following year he took up his present appointment at Reading University.
Professor Duckham's publications include the Fabric of Farming (*Chatto & Windus*) *and* American Agriculture (*H.M.S.O., London*).



In the United States of America responsibility for higher agricultural education lies with the land grant colleges. These differ substantially in both organisation and function from universities as we know them in this country, and from Harvard, Yale, Stanford and the other 'endowed' universities in America. Incidentally, few, if any, of the large number of endowed universities teach agriculture.

There is a land grant college in each of the 48—now 49—States. These colleges, many of which also function as State universities, were, in effect, set up by the Federal and State Legislatures. They provide a public service of learning and local leadership. They are financed, in large part, by Federal and State funds, and their governing bodies are in many cases appointed by the State governments or by machinery which can be amended by State legislatures. British universities, by contrast, are autonomous centres of learning. Although largely dependent on public funds, British universities do not come into close and frequent contact with the general public. This essential difference can be made clear by looking briefly at the agricultural and allied functions of a typical land grant college and at its student body.

In the USA, the college is the centre in its State for *all* agricultural education and advice, apart from some vocational training in agriculture at high schools. It is as though, in Britain, there was in each National Agricultural Advisory Service region a university which was in charge of not only all degree and post-graduate teaching, but also of two-year courses leading to the National Diploma in Agriculture, one-year farm institute courses, short courses of all kinds, the Young Farmers Club, the NAAS, rural domestic economy advice, and much of the research done at research institutes like Rothamsted.

In other words, higher agricultural education and research, though perhaps the leading functions of the agricultural side of a land grant college, are by no means the only ones. This apparent dispersal of effort has, however, the advantage that it keeps the college and its staff closer to the problems of the farmer and his family, and that the rural population think of it as 'our' college. This local proprietary interest in the college is often reflected, through the State legislature, in the degree of financial support given to agricultural education, research and advice. Such interest can, of course, be invaluable. But it may sometimes prove embarrassing to the college. Thus, public pressure for short term *ad hoc* experiments may tend to derange longer term basic research. Or local patriotism may demand that the veterinary surgeons who are currently trained, by arrangement, in an adjoining State, should be taught in a new and largely unneeded local veterinary school, which is costly to build, staff and operate.

Such problems do not, however, in fact loom as large as one might, in theory, expect them to. The high and independent quality of much American agricultural research and teaching shows that academic freedom is not unduly subject to local political and social pressures.

The Student Body

Now let us consider the student today. Every boy or girl of university age has, in effect, a right to enrol in the land grant college of his State, provided that he gets a reasonable report from his high school, where he will reach about 'O' level by British General Certificate of Education standards. In most States, there is no college entrance examination. As there is no screening, many unsuitable students enrol and, as a result, there is a very heavy failure rate, especially at the end of the first year. The students tend to enter university about a year younger than the entry age common in UK universities.

Most students have either to pay their own way through college, or persuade their parents to pay it for them. This is because in the USA there is no general system of state scholarships, Local Education Authority grants, etc., to university students, which means that most students have to do some part-time work in term time. Degree courses, therefore, have to be elastic enough to allow a poor student

to 'earn-while-he-learns', even if it involves lengthening his university career from the usual four up to six or seven years. Even on four-year degree courses, part-time work for 12 to 18 hours a week during term-time is quite usual. It is not surprising, therefore, that many students are well into their twenties, and married, by the time they take their Bachelor's degree.

The make-up and the sources of income of the student body present, it is clear, administrative and time-table problems which would seem very strange to the senior staffs of British universities. The student has to be able to build up his degree piece by piece in a way which fits his particular scholastic wishes and financial means. Degree courses in the UK tend to follow an integrated pattern leading to formal examinations; US courses cannot be so closely integrated. Instead, the student attends an appropriate selection of lectures and, if he satisfies his lecturers, is given so many 'credits'. When he has accumulated enough credits he gets a Bachelor's degree. As no use is made of external examiners from other universities, degree standards could, in theory, vary quite a lot from college to college. But the graduate student is competing for jobs with graduates from other colleges, and, if only for this reason, most colleges are jealous of the academic reputation of their graduates.

The Courses

An example of the build-up for a typical Bachelor's degree is given in Table I; this shows the four-year curriculum for a student taking the animal husbandry option at the land grant college for Virginia. Most agricultural degree courses start off, like this example, with one or two years of suitable

Table I

Land Grant College, Virginia. Four-year course for a Bachelor's Degree, with animal husbandry option

First Year

	Term I	*Term II*	*Term III*
Agricultural Geography	3 (3)		
English Composition	3 (3)	3 (3)	3 (3)
Algebra	3 (3)	3 (3)	
Trigonometry			3 (3)
General Biology		5 (3)	5 (3)
ROTC I*	4 (2)	3 (1)	3 (1)
Electives†	(5)	(5)	(5)
Credits each term‡	(15-16)	(15)	(15)

* Students excused from Military take Physical Education.

† One course each term to be selected from the following:—

Principles of Agronomy	7	(5)
Livestock Production	7	(5)
General Dairying	9	(5)
Basic Rural Sociology	5	(5)
Poultry Production	7	(5)
Principles of Horticulture	5	(5)

‡ These are the minimum requirements. Students who are qualified will be permitted to take as many as 18 credit hours.

Second Year

	Term I	*Term II*	*Term III*
Stock Judging		6 (2)	
General Chemistry	6 (4)	6 (4)	6 (4)
American Government			3 (3)
English Electives	3 (3)	3 (3)	3 (3)
General Physics	3 (3)	3 (3)	3 (3)
General Physics Laboratory	3 (1)	3 (1)	3 (1)
Economic Zoology	5 (3)		
Parasites of Domestic Animals			3 (3)
Anatomy and Physiology of Domestic Animals		3 (3)	
ROTC II or Electives	4 (2)	3 (1)	3 (1)
Credits each term	(16)	(17)	(18)

Third Year

	Term I	*Term II*	*Term III*
Soils Laboratory	6 (2)		
Soils	3 (3)		
Soils *or* Organic Chemistry Lecture		3 (3)	
Meat Production and Preparation			8 (4)
Feeds and Feeding			5 (5)
Animal Breeding		5 (5)	
Advanced Stock Judging		6 (2)	
Elementary Biochemistry and Nutrition	3 (3)	3 (3)	
Biochemistry and Nutrition Laboratory		6 (2)	
English Elective			3 (3)
Elective			3 (3)
Diseases of Domestic Animals		3 (3)	
Genetics	5 (5)		
Electives or ROTC III	(2-3)	(2-3)	(2-3)
Credits each term	(15-16)	(20-21)	(17-18)

Fourth Year

	Term I	*Term II*	*Term III*
Farm Management	8 (6)		
Marketing Livestock, Poultry and Eggs		3 (3)	
Soil and Crop Management			5 (5)
Pork Production	7 (5)		
Beef Production		5 (5)	
Sheep Production			5 (5)
Livestock Management Laboratory		6 (2)	
Livestock Management			3 (3)
Electives	(4)	(4)	
Electives or ROTC IV	(2-3)	(2-3)	(2-3)
Credits each term	(17-18)	(16-17)	(15-16)

Note

The first figure in each column indicates the number of hours per week the class meets during the term.

The figure in brackets in each column indicates the number of credits allowed for the course during the term.

Table II

Curricula and Majors in Agricultural Sciences

Davis Campus, University of California

Agricultural Economics.
Agricultural Education.
Agricultural Management.
Agricultural Production.
Animal Science, specialising in one of the following:—
- Animal Husbandry.
- Animal Physiology.
- Genetics.
- Poultry Husbandry.

Agricultural Engineering.
Entomology and Parasitology.
Food Science.
Forestry.
Home Economics.
Irrigation Science.
Landscape Architecture.
Plant Science, specialising in one of the following:—
- Agronomy.
- Botany.
- General Horticulture.
- Genetics.
- Landscape Management.
- Plant Pathology.
- Pomology.
- Vegetable Crops.
- Viticulture.

Range Management.
Soil Science, specialising in one of the following:—
- General Soil Science.
- Plant Nutrition and Soil Fertility.
- Pedology and Soil Survey.
- Soil Management and Conservation.

Veterinary Medicine.

basic sciences and English and other 'letters' subjects. These are taken up to about 'A' level, British GCE standard. During this time 'professional' subjects, such as animal physiology and crop husbandry, are often introduced, but the main teaching of applied subjects is in the final two years (if the student is on a four-year course).

Each student has to 'major' in a selected field. In effect, he has to specialise to a greater extent than is common in UK universities. The range of possible majors is very large, as may be seen from the example in Table II, which lists the options available at the Davis Campus of the University of California.

Degree Standards

Given the conditions of, and younger age at, entry, and the system of education at the land grant colleges, it is perhaps to be expected that the standard of US Bachelors' degrees would not seem very high in UK academic circles. But a more serious criticism could be that the piece-meal build up of, and the early specialisation within, the degree courses fails to develop an integrated vision of 'the farm as a whole'. This is less of a defect in America than it would be in this country, but it does help to explain why the Americans have recently put such stress on farm management teaching and advice. Unfortunately, however, the approach has been solely economic, whereas, at least in the UK, good farm management lies in the integration of applied economics, applied ecology (crop and animal sciences and husbandry) and applied engineering.

Post-graduate courses leading to Masters' and Doctors' degrees play a big role in the USA, partly because Bachelors' degrees are not highly regarded by research and other organisations requiring graduates with highly trained minds. A one-year M.Sc. course—largely taught—is a common prelude to professional employment; the standard is broadly equivalent to the final year of a specialised Honours Bachelor's Course in the UK. The Ph.D. courses, on the other hand, are rigorous, and search out the weaknesses both in the man and his knowledge. They equate, in the writer's view, with the Ph.D.'s of British universities.

Intellectual Standing

It is easy to be critical of the land grant colleges, which tend to be large impersonal organisations producing large numbers of graduates with Bachelors' degrees that would not be acceptable in the UK. But the high intellectual level of a very great deal of contemporary American research and teaching indicates that post-graduate training, especially of Ph.D.'s, is, in general, rigorous and good. Why then does the US Bachelor's degree not carry more weight? Primarily, the writer suggests, because the younger age at entry, the lowish standards at US High Schools, the somewhat unselected student intake, and part-time work during university terms all combine to hold back the intellectual pace to that of the slowest. The bright student is rather handicapped in his undergraduate days.

On the other hand, a much higher proportion of Americans of university age get to land grant college or university than in Great Britain. This may very well be a social and democratic good, even if it may not, from the academic angle, be wholly desirable.

The Americans, however, are realising that there exists this conflict between the citizen's right to higher education on the one hand and the attainment of higher (intellectual) teaching and first degree standards on the other. Alarmed by, amongst other things, the scientific achievements of the USSR, some American States—for example California and New York—are notably tightening up both entry and degree standards.

Despite these criticisms, we must recognise that there are many aspects of the land grant college system which merit serious consideration outside the USA. One is the tendency for research and teaching to be less divorced than they are in the UK—this proximity is very important for good teaching. Another is the value of taught, or partly taught, M.Sc. degrees. A third is the greater emphasis placed by the Americans on mechanisation and management; in this sense some British degrees seem a little old-fashioned. Finally, there is the widespread realisation that agriculture is something much bigger than farming—hence the courses offered at some colleges in agricultural management. This subject covers the business and technical management of farms, co-operatives and other types of enterprise which cater for the farmer's growing inputs of industrial products, or which market his products for him.

Agricultural Degrees in New Zealand, Australia and Canada

by **M. M. Burns,** Ph.D., *Principal, Canterbury Agricultural College, University of New Zealand.*

The author, *besides drawing on his own experience of agricultural education in New Zealand, writes authoritatively on university courses in Australia and Canada, having recently completed a tour of these countries—and of Britain and the USA—to study university administration and agricultural education and research.*
Born in New Zealand, Dr. Burns graduated M.Sc., Hons. Botany, at Canterbury University College; there followed post-graduate research at the Macaulay Institute for Soil Research, Aberdeen (Ph.D.) and then two years as Commonwealth Fund Fellow in Agronomy at Cornell University.
After his return to New Zealand in 1936 the author became, successively, plant physiologist at the DSIR (of which he is now a Member of Council); Head of the Department of Soil Science, Canterbury Agricultural College; Director, Fertiliser Manufacturers Research Association; and Principal of Canterbury Agricultural College. In 1956 Dr. Burns was President of the New Zealand Institute of Chemistry.

In considering higher agricultural education in New Zealand, Australia and Canada, one must remember that all three countries are young, all are major primary producing countries and all recognised soon after settlement the need for higher education in agriculture.

In each case the Faculties of Agriculture in the universities or the agricultural colleges have contributed to a notable extent to the development of the country through teaching, research and advisory work. They have developed courses along a rather similar pattern but with emphasis on the particular needs of their areas to produce graduates, with a background of the basic and the applied sciences related to agriculture and a capacity to provide leadership in the community.

The pattern of development of higher agricultural education in New Zealand, Australia and Canada has many similarities but there are also significant differences. There are similarities in that in each country the Faculties of Agriculture within the universities or the affiliated colleges have undertaken active rôles in research and in extension as well as teaching, by which they have built up strong public support for the university systems, and they have gradually changed their degree course programmes to include less applied agriculture and more basic science, particularly in biochemistry, physiology and genetics, and to provide opportunities for specialisation.

There are differences in that degree instruction in Australia and Canada, with some important exceptions, is carried out by Faculties of predominantly urban universities, whereas in New Zealand it has been confined, with the exception of the first year, to the wholly self-contained agricultural colleges.

NEW ZEALAND

New Zealand is well served in the sphere of higher agricultural education by two independent, self-contained colleges affiliated to the University of New Zealand which grants the degrees: Canterbury Agricultural College (also known as Lincoln College), founded in 1878; and Massey Agricultural College, founded in 1927. Both colleges offer courses at Bachelor's, Master's and Ph.D. levels. They are primarily residential with extensive farms for instruction and research. Degree courses in agriculture were started at Canterbury Agricultural College in 1910; those in horticulture were started in the 1940s.

The degree courses have been modified from time to time, the most recent changes in 1958 being the introduction of three-year pass degrees in agriculture (B.Agr.) and horticulture (B.Agr. [Hort.]), in addition to regular four-year degrees in agricultural (B.Agr.Sc.) and horticultural science (B.Agr.Sc. [Hort.]), all of which can now be taken wholly at the colleges, whereas previously the first year of science subjects was always taken at one of the university colleges.

Students entering the degree course must have passed the university entrance examination taken after four or five years of post-primary schooling, and indeed the great majority have had a further year in the Upper Sixth form. Such students have had a very good background in the post-primary schools which enables the agricultural colleges to concentrate intensively during the degree courses on providing a sound scientific training.

The courses for the first three years of the B.Agr. and B.Agr.Sc. are identical and fixed; specialisation is limited to the fourth year of the B.Agr.Sc. and to the Master's degree. Students who elect to graduate after three years have had a complete course with a judicious blending of basic and applied science, economics and farm management and are well equipped to enter teaching or advisory work, or to go farming. Those who elect to proceed to the

B.Agr.Sc. specialise along a particular line in the major options of soil science, plant science, animal science, agricultural economics, farm management and agricultural engineering. Masters' and higher degrees may be taken in the same major fields of work and are being taken to an increasing extent. A close liaison is being built up with Divisions of the Department of Scientific and Industrial Research established near the colleges.

All students are required to spend at least 48 weeks in gaining practical experience on the three main types of farms in New Zealand, i.e., dairy, sheep and beef cattle and arable/fat lamb.

The particular points of interest in the New Zealand degree courses are the three years of study common to both Bachelor's degrees which may be taken: the strong science background given in the first two years; the emphasis placed on crops, especially pastures; and animal production in the third year; and the importance given to farm management as the subject integrating the whole of the course in relation to the farm as a business unit.

Enrolments in the degree courses have fluctuated markedly within the past 20 years with a maximum after World War II when about 40 were graduated annually. This number declined in the early 1950s when the number fell far below requirements, but it has built up again very rapidly in the past three years, the first-year intake for 1958 being 110 and for 1959, 140. It seems probable that the acute shortage of graduates which has persisted for many years will be met in the 1960s.

AUSTRALIA

In Australia degree courses in agriculture leading to Bachelor's, Master's and Doctor's degrees are given at the Universities of Queensland, Sydney, Melbourne, Adelaide and Western Australia. The University of New England has degree courses in Rural Science and Agricultural Economics.

Agricultural degree enrolments represent about two per cent. of the total student enrolment and about 80 graduates are produced each year, though this number is expected to rise markedly in the next few years. Separate degree courses in horticulture are not given in Australia but specialisation in the subjects related to horticulture may be taken in the agricultural degrees.

With the exception of Sydney, all universities in Australia require four years for the first Bachelor's degree with emphasis on basic sciences in the first two years and opportunities for specialisation in the third and fourth years. Honours Bachelors' degrees normally require one additional year, and Masters' degrees a further year.

The two most interesting recent developments have been the introduction by the University of Sydney of a three-year B.Agr. degree in addition to the regular four-year degree (B.Sc.Agr.), and the new courses introduced at the University of New England.

The introduction of the three-year degree at Sydney, though criticised strongly by other universities in Australia, has already led to a marked increase in enrolments in that Faculty of Agriculture and in view of the overall shortage of agricultural graduates in Australia the effect of this modification will be very closely watched.

The introduction of the degree courses at the University of New England—a wholly residential institution—is also being followed with interest. The degree in rural science (B.Rur.Sc.) covers four years of training in the fundamental and applied sciences relating to livestock, pastures, crops and soils, leading to depth of appreciation of the soil-pasture-crop and livestock complex as a biological and economic whole. This course is similar in many respects to the degree courses in New Zealand where greater emphasis is also placed on the grazing animal than is usual in most degree courses in other countries.

The four-year degree course in agricultural economics leading to the B.Ag.Ec. provides training in the principles of economics and their application to agriculture.

The requirements for practical work vary from university to university but not less than six months of such experience is required. Usually a part of the time must be spent at one of the State agricultural colleges and the remainder on farms or experiment stations.

On a broad basis the structure of the Australian degree courses is similar to those in New Zealand though the Australian Faculties rely to a much greater extent on the science departments within the same university for many subjects included in the degree, and farm management is given less emphasis as an integrating subject than is the case in New Zealand.

In some universities, notably Western Australia, financial assistance is available for approved students to proceed to Masters' or higher degrees and this support, plus that given by the Commonwealth Scientific and Industrial Research Organisation—directly by way of scholarships and indirectly through the policy of establishing research units at the universities—has led in recent years to a marked development of post-graduate work in the Faculties of Agriculture.

CANADA

In Canada the Universities of Alberta, Laval, McGill (Macdonald College) and Saskatchewan give the Bachelors', Masters' and Doctors' degrees. British Columbia, Manitoba and the Ontario Agricultural College (OAC) extend as far as the Master's degree, and Montreal (Institut Agricole d'Oka) gives the Bachelor's degree.

Agriculture degree enrolments represent about 1.7 per cent. of the total undergraduates in Canadian universities but the proportion is higher in the Prairie Provinces and British Columbia, where the primary industries are of major importance. About 280 Bachelors' degrees are granted each year, but as with Australia and New Zealand, the output of graduates is inadequate to meet requirements. Horticulture is taken as one of the options of the degree in agriculture. Courses in veterinary science are given at Ontario Agricultural College and the Ecole de Médecin Vétérinaire, affiliated to the University of Montreal, with an annual output of about 90.

With the exception of Macdonald College, which is the Faculty of Agriculture of McGill University and is situated

some 20 miles from the university, and OAC, which is under the Ontario Department of Agriculture and affiliated to the University of Toronto, both of which are self-contained institutions, teaching the whole degree courses and with their own departments of the appropriate arts and science subjects, all the other English-speaking universities have Faculties of Agriculture on the main campus and the degree courses are taken in association with the Arts and Science Faculties. Thus Macdonald College and OAC, though offering courses for other degrees as well as agriculture, are somewhat similar in organisation to the New Zealand colleges while the other universities are more closely comparable with those in Australia.

The general division of the Canadian degree courses, all of which require four years for the Bachelor's degree, into predominantly basic sciences in the first two years with opportunity for specialisation in the next two years is broadly comparable with the Australian and New Zealand approach. Unlike these two countries, however, which have a rather small number of large subjects each taken over a full three-term academic year, the Canadian universities have a much greater number of smaller subjects taken over a two-semester academic year with each semester being a separate teaching period.

As would be expected, Canadian courses pay special attention to the plant sciences and to the feeding, housing and management of livestock, whereas in New Zealand and Australia, where livestock are relatively more important and are not housed, the emphasis is primarily on the soil-plant-grazing animal complex. Furthermore, the Canadian universities include in their degree courses additional subjects from the humanities and the social sciences to a far greater extent than is the case in Australia and New Zealand.

Indeed, the Canadian degree courses are much more closely related to those given in the Land Grant colleges of the United States than to those given in other Commonwealth countries. A further similarity between the Land Grant colleges of the United States and the Canadian universities is that they too, in most cases, act as the centre for the Provincial Agricultural Advisory Services and have on the campus both Provincial and Federal Research sections, a real stimulation for post-graduate studies. Indeed, the pursuit of post-graduate degree qualifications, especially at the Ph.D. level, and for which there are many scholarships, is a much more significant feature of the Canadian universities than it is of those in either Australia or New Zealand.

Reading Agriculture in Britain

by **M. McG. Cooper,** F.R.S.E., *Dean of Agriculture, University of Durham.*

The author, *who has established a reputation as one of the liveliest commentators on agriculture since the war, was born in New Zealand. After taking his B.Agr.Sc.(N.Z.) degree, in 1933, he went up to Oxford as a Rhodes Scholar, specialising in agricultural economics and obtaining a B.Litt. and Dip.Rur.Econ. He was a Rugby football Blue and played three years against Cambridge—the last year as Captain. He was also 'capped' for Scotland.*
Returning to New Zealand in 1937, the author held appointments with the DSIR and at Massey Agricultural College until the war, during which he served as an infantry officer. In 1946 he became head of his former department (Dairy Husbandry) at Massey. Appointed to the newly-created Chair of Agriculture at London University (Wye College) in 1947, Professor Cooper remained there until 1954, when he moved to his present post at Durham University. Especially interested in animal production, and in the grazing animal in particular, he is President of the British Grassland Society.

The character of agricultural education at the university level in Britain has changed considerably over the past 10 years. There has been a greater tendency to base teaching of the husbandries on an appropriate foundation of pure and applied sciences, and an increased emphasis on economics in order to provide a better understanding of the principles of farm management. In most university departments this has become the climax subject for courses in general agriculture, because it provides an ideal vehicle for gathering the loose threads of other teaching. Another change has been the increased emphasis on Honours degrees with some considerable measure of specialisation, which is inevitable, for agricultural science covers such a wide field that it is virtually impossible to obtain a real depth of knowledge in more than one aspect during a four-year course of study. Finally, there has been the disappearance from many syllabuses, at least so far as examination is concerned, of such subjects as surveying and levelling, farm accountancy and agricultural law. These have had to go because otherwise there would not be sufficient time to do justice to the hard core subjects, which are essential if there is to be a proper understanding of the management of soil, plants and animals.

The increased importance of Honours degrees is logical

for a variety of reasons. In the first place it puts the graduate in a stronger position when he is seeking employment in competition with graduates with Pass degrees, or with those whose discipline has been in a pure science. Secondly, the Honours degree calls for a higher level of teaching and not only does this give the lecturer concerned a greater satisfaction, but also it puts him on his mettle and so prevents him from going to seed: there is no sterner disciplinarian for the university teacher than a lively class of Honours students.

Secondly, there is the corresponding effect on the student who is encouraged to express his academic potential. There is a grave danger of a man with a good brain just coasting along in a Pass course without really developing his critical faculties. The Honours degree, with its classified results, provides an incentive for deeper reading and thought. Thirdly, the Honours degree is a preparation for post-graduate research because the good Honours graduate will have read deeply in some aspect of his subject and will have something of the background that is a necessary pre-requisite for research in that field.

Place of the Pass Degree

This does not imply that the Pass degree is outmoded and no longer has a useful function. To the contrary, for, with proper teaching, the course provides an admirable preliminary training for the practice of agriculture, or for advisory work. These Pass degrees in a sense are a more fundamental edition of the two-year courses in general agriculture which are given at agricultural colleges, for there is an additional year of study for students who at school have reached a minimum academic standard of University Entrance. There is both the background and the time, too, for teaching in terms of principles rather than descriptively to make the course of study reasonably dynamic. This is essential, for three years is a pitifully short time in which to cover a subject so wide as agriculture, and one cannot hope to turn out a complete agriculturalist who is ready made for a job. The most one can hope for is the development of an attitude of mind and the creation of some perspective in thought. This can be obtained if the course of study is based on principles, but if the husbandries and farm management are taught empirically, knowledge will tend to be encyclopaedic and will soon become dated.

There are two methods of entry into an Honours school. One is based on direct entry in the first year into a special Honours course of three or four years' duration. Generally it is required that the entrant has good passes in three Advanced level science subjects, which means that he has reached a standard approximating that of the old Intermediate Examination. This system has the advantage of keeping 'bright' students together and of allowing teaching to be so designed that it caters for the needs and ability of the class. There is, of course, the disability of knowing what to do with the man with a good school record who, when it comes to university education, does not sustain his early promise. Third Class Honours is often less of a recommendation than the holding of a Pass degree.

The second method of entry into an Honours school which is adopted by some university departments obviates this problem. All students, regardless of pre-entry standards, enter the Pass course and after three years they sit the final examination on which results the Pass degree is awarded. The best of these students, judged on examination results, are permitted to enter a fourth year of study leading to an Honours degree. Such a system gives a chance to the late developing student—and there are many of these taking agricultural courses; very often they have been country students who have been at a small grammar school where the quality of science teaching is not good, and so they come to university with a handicap. If they have the inherent ability they will overcome this handicap to earn the academic distinction they deserve.

This delayed entry into an Honours school is best suited to courses in general agriculture which provide a useful preparation for such specialisations as crop or animal husbandry, farm mechanisation, or farm organisation and management. All these specialisations call for a broad foundation of knowledge. For example, the animal husbandman must have an understanding of the nutrition of the grazing animal and this in turn will call for a knowledge of soil and pasture management. Men in such specialisations must be able to relate their particular interest to the complex of agriculture.

Delayed entry to Honours is less suited to such specialisations as agricultural zoology, chemistry or botany. Here the agricultural graduate is in more direct competition with graduates in pure sciences. Here, too, there is a much greater need to develop the appropriate pure science disciplines and in a large measure the teaching of the agricultural subjects such as crop and animal production becomes ancillary to the basic science and its application to agriculture. Through its very nature such a course right from the outset acquires the character of an Honours course and it does not reach a logical end till the fourth and final year. Indeed, this also applies in a measure to the course in general agriculture.

The final Honours year is a very satisfying one to the student who in his Pass course has been something of a sponge, absorbing whatever he can from lectures or prescribed reading. In his fourth year he is given a problem to study and he has to use his initiative. The good student gains in confidence and authority and his capacity for judgement is enlarged. He is a very different person from the one who completed a Pass degree a year previously.

Science or Agriculture?

Returning to the question of specialised science options in agriculture, there is a school of thought in Britain which considers that the proper entry into such a field as soil chemistry or plant breeding is by means of an Honours degree in the appropriate pure science, followed by post-graduate study in the applied field. This looks to be thoroughly logical on paper but in practice it does not always work.

The man who from the start has an agricultural background has an advantage because he has a better under-

standing of related problems. Furthermore, he has taken an agricultural degree because he likes agriculture, though his interest may be in a scientific field. He is not turning to agriculture after graduation because there is nothing better for him to do. So far as such a subject as chemistry is concerned, there are generally plenty of good openings in industry and it is very seldom that the good Honours chemistry graduate will seek employment in agriculture. This field would be very poorly served were it not for the supply of agricultural chemists that are being turned out by several of the British universities.

It has been realised increasingly by those responsible for training such specialists in agricultural science that the basic training in sciences must be sound. There is, of course, no detriment if the materials of agriculture are used to provide that basic training, and there is the by-product of an understanding of agricultural problems in the process. Men like Professor R. L. Wain, of Wye College (University of London), have demonstrated very convincingly that such a subject as agricultural biochemistry, properly taught, can provide a very adequate scientific discipline.

This question of a scientific discipline in agricultural education is, of course, an important one and the problem is that there are so many that they compete with one another. Obviously all cannot be taken to the point that an authority in any one of them would desire. It is generally recognised in Britain that chemistry is essential, for only by an understanding of chemical principles can one obtain an understanding of soil plant relationships and of plant and animal physiology. This in turn gives an understanding of plant and animal ecology which, treated from an economic angle, is essentially the study of agriculture. More and more courses in agriculture in Britain have tended to follow this sequence of basic science, applied science and field application and, in the process, have given even Pass courses a reasonable status in comparison with other undergraduate studies.

Post-Graduate Courses

At the post-graduate level all universities offer facilities leading to M.Sc. or Ph.D. degrees, which are awarded on the submission of a thesis. Some of them also provide one-year courses leading to post-graduate diplomas generally in specialised fields such as agricultural economics or farm management. There are at least two universities which offer M.Sc. courses by examination—Durham in Agricultural Engineering and London (Wye College) in Poultry Husbandry. Generally, M.Sc. by examination is not popular, especially if it requires work in subjects which are essentially taught and examined at an undergraduate level. This is sometimes unavoidable in present circumstances, where one is required to graft two very different courses, such as agriculture and engineering. There is a great deal to be said for a first degree in agricultural engineering, with engineering taught as the prime discipline and agriculture as the ancillary.

Most departments of agriculture offer normal post-graduate teaching over a fairly wide range, but inevitably some specialisation occurs, as a result either of special facilities or of staff who have a high reputation in their field. For many years the Cambridge School of Agriculture provided an example of a notable specialisation. Men like Hammond and Woodman, through the quality of their work in animal physiology and nutrition, attracted post-graduate students from all over the world. To a large extent, however, the mantle of the university has been taken over by research institutes, which are recognised by adjacent universities as centres for post-graduate studies. Such centres as East Malling, Rothamsted and John Innes, for instance, will have students who are accepted by the University of London for higher degrees. The specialised research institute generally has resources far beyond those of a university department, so it is natural that the mature research student will be attracted to the former, especially if he is to be associated with some one who is a full time research worker, rather than a part timer, which is the fate of most university men.

The Agricultural Research Council has helped to counter this to some extent by setting up Research Units at some of the universities in order to give outstanding university men facilities to promote research in their line. As a result, there are some university departments which can offer in some fields opportunities at least as good as those of a competing research institute. One hopes that this development will become increasingly important, for the best stimulus there is to teaching, even at the undergraduate level, is the active prosecution of research within the department. It brings to students a realisation that they are not studying a finite subject, for there are new and exciting paths still to be explored. Though they may not be required to map these paths, because their work will be in other spheres, they nevertheless receive the stimulus of being associated with people who are looking beyond the fringe of knowledge. This creates the essential difference between university teaching as opposed to technological teaching. One hopes it will make students better able to make their contributions in a rapidly changing world.

Agriculture at European Universities

An account of facilities for higher education in agriculture in OEEC countries is being prepared as a special supplement to *FATIS Review* and is due to be published this summer. The *Review* is published by the Food and Agricultural Technical Information Service of OEEC at 2 Rue André Pascal, Paris 16e, France.

Agriculture at University College, Ibadan

by **R. J. McIlroy,** *Dean of the Faculty of Agriculture*

The author, *who has held his present appointment since 1957, is a graduate of the Universities of New Zealand and Birmingham. From 1934 to 1952 he held a number of practical and academic chemistry posts, in New Zealand until 1948, and, from 1948, as Professor of Chemistry at University College, Ibadan. In 1951 and 1952 he was Dean of the Faculty of Agriculture at Ibadan, being appointed in 1952 Director of the Indian Tea Association's experimental station at Tocklai, Assam, where he remained until 1955. That year he became Professor of Agricultural Chemistry and Dean of the Faculty of Agriculture, University of Khartoum. He returned to Ibadan in 1957. Professor McIlroy is the author of two books, and of numerous papers in scientific journals.*

When the Department of Agriculture at University College, Ibadan started teaching in 1950, it did so with an entry of one student. By 1958, there were 35 students and the output of graduates is now about 10 per year. With the approach of independence for Nigeria in 1960 the need for trained Nigerian agriculturalists becomes greater than ever before, and it is to be hoped that within the next few years the number of students will greatly increase.

The Department of Agriculture was established in October, 1949; its establishment was made possible through an endowment of £1,000,000 by the Nigeria Cocoa Marketing Board. £50,000 of this endowment was allocated to capital expenditure and the remainder to produce an annual income (£35,000) for the running of the Department and an experimental farm. A further capital grant of £35,000 from the Cocoa Marketing Board was made in 1955.

For the year 1957 to 1958, the total cost of the Department and farm was £60,000, of which £37,000 was spent on staff salaries and teaching equipment and £23,000 on labour and upkeep of the farm. Sale of farm produce returned an income of £10,000, so that the College was required to supplement its grant income by only £15,000.

The entrance requirement for the three-year course in agriculture, leading to the degree of B.Sc. (Agric.) of the University of London, is completion of the Intermediate course in chemistry, botany and zoology, and a pass in a preliminary examination in physics. Most students, before entering the College, have already had some experience of agriculture at the School of Agriculture, Moor Plantation, or as agricultural assistants in the Ministry of Agriculture, or as 'tillers of the soil' on their fathers' farms. Those whose preliminary field experience is considered to be inadequate are required to spend one month working on the College farm before their acceptance by the Faculty of Agriculture. During their degree Course, students spend part of their vacation working on the College farm and part on conducted tours of the Eastern and Northern Regions. In the course of these tours they become acquainted with the diverse agricultural crops and practices of the different parts of Nigeria.

The degree course is run in Special Relationship with the University of London, and teaching conforms to the University's standards. Syllabus and examinations are agreed between the University and College, and examination scripts are marked at Ibadan and again in London. Each year the University sends a visiting examiner to Ibadan.

At its inception, the staff of the Department consisted of a Head, and one lecturer each in animal husbandry and health, tropical agriculture, soil science, agricultural botany, entomology, plant pathology and agricultural economics (chemistry was taught in the Faculty of Science). A lecturer in animal nutrition and a second lecturer in animal husbandry have since been appointed. The author was appointed Professor of Agriculture and Dean of the Faculty in 1957, before which time there had been a Professor for only a few months in 1955.

The three-year Course for the General degree of B.Sc. (Agric.) consists of two parts:—

Part I	Organic Chemistry
	Pedology (Soil Science)
	Botany
	Zoology
Part II	Crop Production
	Animal Production
	Agricultural Organisation

Part I is a one-year Course, while Part II is spread over two academic years. Since 1957 the teaching of Part I, with the exception of pedology, has been undertaken by the Faculty of Science. This arrangement, although not ideal, reduces the teaching load on the Department of

Agriculture, and allows staff some time for research without which teaching loses its vigour and inspiration.

In 1957 an Honours course in agriculture was introduced and the entrance requirement was modified to permit direct entry to the degree course by students who have completed the Cambridge Higher School Certificate examination with passes at Advanced Level in chemistry and biology, or botany or zoology. The syllabus for the Honours course is similar to that of the General degree, but first and second class Honours or a pass degree are awarded. While undergraduate courses deal with the principles of agriculture, local material is used whenever possible, and the teaching has a bias towards tropical agriculture throughout.

The College Farm

The College farm covers about 400 acres, of which about 140 acres form a teak plantation. Maize, yams, cassava and sunflower are grown as food and forage crops and oil palms, rubber, cocoa and coffee as permanent tree crops. The major fruit crops are citrus, pineapple and bananas, while minor quantities of coconut, cashew, guava, paw-paw and sunn hemp are cultivated for demonstration purposes.

An area of 62 acres is laid down in grass/legume pasture (principally Star grass [*Cynodon plectostachyum*] and *Centrosema pubescens*), but this area is being considerably extended with the development of a grassland research programme.

A herd of 60 White Fulani (Bunaji) Zebu cattle is maintained for observation of the incidence of and tolerance to tropical insect-borne diseases and for grazing trials; there is a demonstration and experimental flock of 60 local dwarf sheep and a few goats, and the poultry section consists of about 4,000 birds of various breeds, together with small flocks of turkeys and ducks. There is a breeding stock of pigs of about 30 Large White, Large Black and Tamworth animals. There is also a commercial piggery of about 100 animals.

Research

Endowments from the Rockefeller Foundation, the Federal Government and the Western Region Production Development Board have greatly facilitated agricultural research at the College, and investigation of grain storage problems with special reference to maize and guinea corn is being carried out with equipment provided by the West African Stored Products Research Unit. Research is currently divided between grassland, animal production, agricultural economics and agricultural engineering.

The Imperial College of Tropical Agriculture

by **G. A. C. Herklots,** *Principal.*

The author *describes himself as a 'Jack-of-all-trades'. He has taught at the University of Hong Kong, where fisheries research was one of his occupations. For six months he was with a nutrition survey in Nyasaland, and then he became scientific adviser to the Food Controller in Hong Kong. As a prisoner of the Japanese, he acquired, he tells us, much valuable first-hand knowledge of poverty and hunger.*
Later on, Dr. Herklots became Secretary for Development in Hong Kong, with interest in agriculture, fisheries, forestry, co-operatives, and fish and vegetable marketing.
Next, he spent five years as a senior adviser in the Colonial Office, before going to Trinidad in 1953. He has travelled very widely and has written books on a variety of subjects, including birds, fish, vegetables and natural history.

The British islands in the West Indies are now passing through a very interesting and rather involved period in their evolution from dependent Colonial territories towards the objective of a free unified organisation with Dominion status in the British Commonwealth. A milestone was passed on 3rd January, 1958, when Lord Hailes was sworn in as Governor-General of the new Federation of the West Indies.

The Imperial College of Tropical Agriculture is a unique institution and a review of its past is of interest before considering its present rôle. Great men with vision played their part in its creation. In 1898 Mr. Joseph Chamberlain founded the Imperial Department of Agriculture in the West Indies. In 1902 Mr. Norman Lamont suggested that the Colonies needed an agricultural college of university standing and in 1913 proposed that the college should be in Trinidad and that the headquarters of the Imperial Department should be transferred there also. The First World War delayed serious consideration of this proposal.

In 1919 Viscount Milner, then Secretary of State for the Colonies, appointed two committees: the first was set up to examine and report on the agricultural services of the Colonies; the second was the Tropical Agricultural College Committee under the chairmanship of Sir Arthur Shipley, Master of Christ's College, Cambridge. This committee, in a report submitted in 1921, recommended the formation

of a college and in September of that year the West Indian Agricultural College came into existence. In 1926, when the College was incorporated by Royal Charter, it was given its present name at the suggestion of the Rhodes trustees, who subscribed £5,000.

The first object of the College was to provide agricultural instruction to residents of the West Indies. The second, following the recommendation of a committee appointed by the Rt. Hon. J. H. Thomas, then Secretary of State, was that it should become the training ground in tropical agriculture for graduates selected for the agricultural services of all the Colonies.

Amongst the recommendations of the West Indies Royal Commission appointed in 1938 by the Rt. Hon. Malcolm Macdonald, then Secretary of State for the Colonies, and published in 1940 was this: 'The centralisation of all major research and investigation at the ICTA which would thus add to its present functions the duty of serving as a research station for the West Indies'. This was implemented in part by the creation of research schemes for cocoa, banana and soils in 1946 to 1947 and consolidated by their incorporation in the Regional Research Centre created at the College in September, 1955.

Range of Courses

The Imperial College of Tropical Agriculture today stands on three legs: undergraduate teaching, post-graduate teaching and research, and its stability is due to the maintenance of balance between these three functions.

At the present time two three-year undergraduate courses are given: one in tropical agriculture leads to the DICTA (Diploma of the Imperial College of Tropical Agriculture), the other, in sugar technology, to the DICTA (Sugar Tech.). The latter course is normally recommenced every fourth year.

Graduates selected for agricultural appointments in H.M. Overseas Service normally do one year at Cambridge followed by a year in Trinidad leading to the DTA (Trin.) (Diploma in Tropical Agriculture). Graduates in agriculture from West African universities may be permitted to take the AICTA (Associateship of the Imperial College of Tropical Agriculture) after 12 months' residence, though this course for graduates from temperate countries normally covers two academic years.

Since the Royal Charter was granted in 1926 more than 1,200 students have taken undergraduate and post-graduate diplomas at the College and of these more than 100 are now employed in Government service in the West Indies Federation.

This year's entry of students is worth brief study. There are 42 undergraduates from 16 different territories, of which nine are islands within the Federation, with students also from British Guiana and British Honduras; there is one student each from Aden, Fiji and Kenya and one each from Martinique and Surinam.

The 57 post-graduate students have taken their degrees in 23 different universities, of which 18 are within the British Commonwealth, the other five being Lisbon, Kwangsi and three in the USA. These post-graduates are destined to serve in 18 different territories in the British Commonwealth of which Northern Rhodesia (eight) and Tanganyika (five) this year claim the most. One each goes to the Solomon Islands, to Fiji, the Seychelles, Somaliland, New Guinea and Hong Kong. A few men will serve in foreign tropical countries.

This survey gives an idea of the remarkable range of both background and future of the undergraduates and graduates who come to the College. A very encouraging feature is the slow but steady increase in the number of graduates from the two West African university colleges who come to Trinidad to complete their training either as general agricultural officers or as specialists in entomology, plant breeding, soil science and the like.

All members of the teaching staff are given time and facilities for doing research which is as free in its scope as conditions permit. In addition there is the Regional Research Centre at the College with a senior staff establishment of 28. The directed research carried out by the staff of the Centre is mainly long-term into fundamental problems affecting in particular the West Indies. It includes banana breeding—shared at the time of writing between Trinidad and Jamaica, but in the future to be located entirely in Jamaica. Every important problem concerned with the growth of cacao trees, the fermentation of the cacao beans and preliminary assessment of their quality is investigated and this research is intended to be of universal application.

Soil and land-use surveys form a most important branch of work. A team of three has been in Jamaica for several years and teams have carried out surveys in British Guiana, St. Vincent and Grenada. Reports of these surveys are now being published together with maps. A team of three has recently started a survey in Dominica in the Leeward Islands. Research is also directed towards the improvement of the main food crops of the peasants and towards the investigation of the pests of stored products, in particular rice. There is a research statistician on the staff and a unit which is responsible for seismic and volcanological research and investigations throughout the West Indies.

The Department of Sugar Chemistry and Technology is responsible for the British West Indies Sugar Research Scheme, now very largely financed by the sugar industry.

Future Plans

At the time of writing negotiations for the integration of the College and the University College of the West Indies situated in Jamaica are well advanced. One result of such integration would be that a degree course leading to the B.Sc. (Agric.) would take the place of the diploma course. The Royal Charter of the College would be rescinded and the College would come under the direction of the Council of the University College. The training of sugar technologists, post-graduate teaching and research would continue very much as at present and it is hoped that the College as a part of a University would attract to an even greater extent the support of countries within the Commonwealth and their students.

Training for Colonial Agricultural Services

by **G. W. Nye**, C.M.G., *Agricultural Adviser, Colonial Office, London.*

The author *is particularly well qualified to write on his subject, having been engaged in Colonial agricultural advisory work for some 35 years. Appointed Agricultural Adviser to the Colonial Secretary in 1956, he has been at the Colonial Office (as Assistant, and later Deputy, Agricultural Adviser) since 1947.*
From Forest School, the author went to Wye College, where he obtained a B.Sc.(Agric.) degree, and thence to the Imperial College of Science & Technology, Cambridge University and the Imperial College of Tropical Agriculture. In 1924 he went to Uganda, where he was to spend the next 20 years—16 of them as a botanist, two as Deputy Director of Agriculture and two as Director of Agriculture. There followed three years in Nyasaland (1944-1947) as Director of Agriculture before appointment to London.

In this history of training for tropical agriculture the author points out that although it had been for long appreciated that such training could only be satisfactorily done in the tropics, it was not until after World War I that this became possible. The first training plan started in 1919 with the Empire Cotton Growing Committee's [now Corporation] scholarship scheme for graduates who would be working in cotton areas. This was followed two years later by the opening of a specialised training centre, the Imperial College of Tropical Agriculture [its work is described in this issue]. Although training was available, however, development was slow between the two world wars, and the author says that it is only within the last two years that supply has satisfied the demand for suitably trained agronomists.

The first Colonial Department of Agriculture, the Imperial Department of Agriculture in the West Indies, was established in 1898, largely to assist sugar planters who had fallen on evil days. The success of this first attempt at advisory work in the British Colonies gave the lead to other colonial territories to set up small scientific departments whose work was initially directed towards making collections of plants and insects and introducing new crops. As these departments were gradually enlarged, they were eventually split into separate organisations covering agriculture, forestry and veterinary services.

Before the First World War Departments of Agriculture were largely composed of unqualified officers, sometimes with one or two specialists. It was not until the end of the war that it was appreciated what a large, almost untouched field for economic development lay in the mass of peasant farmers, particularly in the African territories, and that in order to develop this field a much more scientific approach to the problems was necessary. There then began a slow but steady expansion of the Agricultural Departments, staffed with graduate specialists and field officers, but it was not long before it was recognised that a degree alone was not a sufficient qualification for both these types of officer. The wide range of conditions and the great variety of problems met with in the tropics made additional training, designed to broaden the outlook and to develop the critical faculties, essential. Furthermore, an introduction into tropical agriculture was clearly desirable.

It has always been accepted in the United Kingdom that it is impracticable to train men in tropical agriculture outside the tropics, but it was not until the West Indian Agricultural College, later to become the Imperial College of Tropical Agriculture, was founded in 1921 in Trinidad that any satisfactory facilities for post-graduate training in tropical agriculture became available. The Empire Cotton Growing Committee, later formed into the Empire Cotton Growing Corporation, was in fact the pioneer of post-graduate training for overseas Agricultural Officers and specialists. In 1919 this Committee started a scholarship scheme designed to give post-graduate training to graduates in agriculture or natural science, with a view to appointment in cotton-growing territories, either to its own staff or to supplement the staff of Agricultural Departments. In 1925 the Colonial Office followed suit, and awarded 16 scholarships to graduates for eventual appointment as Agricultural Officers or specialists. These scholarships were normally awarded for a two-year post-graduate training period, the first year of which was spent either at Oxford or at Cambridge, and the second at the Imperial College of Tropical Agriculture. These scholarships carried no guarantee of employment and particularly in the 'lean thirties' students were often left at the end of their two years' specialist training with no jobs. Since the introduction of post-graduate diplomas in agriculture and agricultural science at Cambridge University, the Colonial Office has sent its agricultural probationers to that University for their first year's post-graduate training and have continued to use the Imperial College of Tropical Agriculture for the second year. Nearly 800 graduates have been so trained and posted overseas. (*Continued on next page.*)

The Unified Colonial Agricultural Service, covering both research and extension work in colonial agriculture, was constituted in 1935. This Service was open only to graduates who had undergone the two years' post-graduate training.

Due largely to financial difficulties, the growth of Departments of Agriculture during the period between the wars was very slow and up to the end of the Second World War the qualified staff available in most territories was very far below their needs. After the war there was a great impetus to agricultural development. More money was available locally and the Colonial Development and Welfare Acts made comparatively large sums available for agricultural development as well as for agricultural research. There began to be a very heavy demand for Agricultural Officers and specialists and it was clear that in order to attract the best men into the Service the old system of recruitment and training with no guarantee of employment at the end would no longer be attractive; accordingly, the Colonial Office Scholarship Scheme was changed. Recruits were only accepted for training against specific vacancies and they were guaranteed employment in one of the Colonial Departments of Agriculture after satisfactory completion of their two years' post-graduate training.

Increasing Demand

Demands continued to increase, and whereas between 1925 and 1945 a total of 314 graduates in agriculture, horticulture and natural sciences received post-graduate training and were appointed to the Colonial Agricultural Service, in the 12 years 1946 to 1958 more than 450 were recruited, trained and appointed. Only within the last two years has recruitment caught up with the vacancies.

Since the Second World War faculties of agriculture have been established in a number of the overseas University Colleges and it is expected that graduates from these Colleges will gradually replace UK expatriates. Unfortunately, the numbers coming forward to read agriculture have so far been disappointingly small and it will be many years before sufficient numbers are available to ensure that Departments of Agriculture are fully staffed by their own nationals.

It is a remarkable tribute to those who had the foresight to introduce post-graduate training for those destined to work in the tropics that after 33 years this system is still considered to be very satisfactory. At a Conference of Directors and Senior Officers of Overseas Departments of Agriculture, held at Wye College last September, it was recommended that the present system of post-graduate training for graduates destined for Agricultural Departments should continue and should also apply to graduates of overseas University Colleges. The hope was expressed that these Colleges would establish their own post-graduate schools and then that the second year of post-graduate training for expatriates might be done at the University College serving the region to which the officer would be posted, rather than at the Imperial College of Tropical Agriculture.

As progress is made in colonial agriculture, so it becomes necessary to increase and improve the tools of the trade, particularly of those who will be engaged on extension work. In addition to the diploma course at Cambridge, probationers receive short courses in field surveying, irrigation, extension methods, photography, the interpretation of aerial photographs, and other necessary subjects.

In view of the very important part that women play in agriculture in many tropical countries where, in addition to their traditional tasks of child-bearing and rearing, water-carrying, fuel collection and food preparation, they are often responsible for the cultivation of at least the food crops, it has often been suggested that there should be women graduates on the staffs of Agricultural Departments. There has, however, been a general reluctance to employ them, largely because after expensive post-graduate training they are so frequently lost to the Service by marriage. However, Uganda has recently taken a progressive step by recruiting two women agricultural graduates to its agricultural field staff. After post-graduate training, particularly in teaching methods, they will make surveys of the part played by women in agriculture and will then prepare and hold courses of instruction for women at farm institutes.

It is quite clear that the greatest progress is made in those territories which have an adequate advisory staff. The spectacular success of land consolidation and farm planning in some of the African areas of Kenya is in a large part due to the comparatively large staff available. Personal touch with the individual farmer is the essence of extension work and this means very much larger staffs than exist in most territories today. In one of the largest territories, Northern Nigeria, there is still less than one extension officer for every 10,000 farmers. Highly trained professional staff are not enough: they must be supported by large numbers of subordinate staff trained at local agricultural colleges and farm institutes.

Research

But an extension service, however well staffed, is of little use without adequate specialist and research staff. There must clearly be a correct balance between the two, with the research men providing the extension officers with the results of their investigations—new varieties, correct fertiliser requirements, new systems of husbandry, disease and insect pest control while the extension staff must present the problems they meet in the field to the specialists for investigation.

The research needs of the Colonies are met by specialists on the staffs of Agricultural Departments, by commodity research stations and also by regional research organisations, such as the East African Agricultural and Forestry Research Organisation, based at Muguga, Kenya, and the West Indian Regional Research Centre based at the Imperial College of Tropical Agriculture. Largely to assist those territories which cannot afford to carry specialists on their departmental establishments, a number of United Kingdom based pools of specialists have recently been established covering entomology, plant pathology, soil surveys and stored products.

Graduates for the Pesticides Industry

by **J. I. Hendrie,** *Manager, Agricultural Department, The Shell Petroleum Company.*

The author *joined the Shell Petroleum Company in 1947. Since then he has been engaged in various capacities in the development of the Company's agricultural chemical interests and his work has brought him first-hand experience of crop pest and disease problems in most parts of the world.*
Leaving Gresham's School in 1936, Mr. Hendrie started to read medicine in London, but after a year he decided to change to agriculture and went up to Jesus College, Cambridge, where he took his degree. War service with the Royal Artillery (Anti-Aircraft) in the UK and India was followed by a short period of teaching before the author joined Shell.

It is well known that many agricultural graduates are employed in industry and commerce, but many people—including both university teachers and the undergraduates themselves—are not always clear as to what type of men with what type of qualifications are required by commercial organisations handling agricultural chemicals.

'Agricultural chemicals' is a term generally used to cover pesticides—i.e. insecticides, fungicides, acaricides, herbicides and soil fumigants, or nematocides. Chemical fertilisers, which are materials of comparatively long standing, are usually considered to be a separate, though allied, industry. The following notes are concerned mainly with pesticides.

Synthetic organic pesticides, of which there are some hundreds of formulations in commercial production, have grown rapidly in numbers and volume since the last war. The discovery of the insecticidal properties of DDT in 1939 and of BHC a few years later, and also the discovery of the selective herbicidal action of 2,4-D and MCPA, opened up new avenues of research within the chemical industry, and present-day agricultural chemicals stem from these discoveries.

The need for pesticides is twofold. First, they enable more and better food to be grown. In the world today, the population is over 2,500 million and is growing all the time at the rate of approximately one per second. Apart from any increase in population, more than half the peoples of the world are undernourished. This situation, coupled with the fact that cultivable land is being lost at the rate of some 10,000 acres per day, indicates the importance which is now attached to the use of agricultural chemicals.

Apart from the need to grow more food from an ever declining amount of cultivable land, the food which is harvested can be attacked by a variety of pests before it reaches the consumer—altogether it has been estimated that during the growing, harvesting and storage of world foodstuffs, 30 per cent. is lost to pests or diseases.

In the second place, insecticides are now widely used to control vectors of human disease. As an example of the importance of insect-borne diseases, it has been estimated that malaria alone strikes 150 million people a year and kills 1½ million.

The uses for pesticides are many and varied and the problems are universal. The larger firms producing pesticides are concerned with markets all over the world and so the problem embraces many hundreds of economically important pests or diseases attacking practically the whole range of crops cultivated under varying conditions of climate, soil type and, indeed, of legislation—not to mention the wide divergences of outlook and temperament on the part of consumers in different parts of the world.

The industry concerned with these problems requires staff for research, manufacturing, distribution and marketing but this short article must confine itself to the marketing side. While without question there is hardly a country or crop which cannot benefit in some way from modern agricultural chemicals, benefit can only be gained when the chemical has been correctly chosen and properly applied.

Technical Service

Frequently, the consumer is not only unable to decide which material he requires out of the many which are available, but often he is unable to determine the nature of his problem. We therefore find that one of the first fundamental principles of marketing agricultural chemicals successfully is the ability to demonstrate their use and the advantages which such use can bring about; the pest or disease therefore has to be identified so that the correct chemical may be chosen. The type of formulation to be used, the stage in the life cycle of the pest at which it should

be applied, the dosage rate and the method of application are all factors which must be taken into consideration. In our field, in fact, technical service is of paramount importance.

It would seem, then, that we require an individual who must not only have a very wide knowledge of agriculture, but who must also be part entomologist, part plant pathologist (or physiologist in the case of herbicides), part chemist, part engineer. In the public health field he must understand the nature and habits of the insect vector and the life cycle of the pathogen. Above all he must understand the 'farmer' and his problems (the 'farmer' may be a scientifically trained manager of a large estate or a peasant smallholder).

In addition, our man should be able to talk to research workers and government officials, whose job it is to develop or control the use of pesticides in whatever country the operation is being undertaken; equally he may need to have discussions with medical officers responsible for administering those public health programmes which are based on the use of insecticides. He must be able to gain the respect and confidence of these widely different individuals.

On the more practical side, an agricultural chemicals representative must know how to lay down field trials with chemicals and how to assess the results. In all circumstances he must be a man who can improvise. He may be thousands of miles away from his headquarters in a strange country where facilities are inadequate or non-existent and where resourcefulness may be the key to success or failure.

From all this it seems clear that the man we require is one whose training ideally should embrace the whole range of the natural sciences; a man who is able to understand the mentality and outlook of both the specialised expert and the farm worker, and who can work on his own. One might add that some knowledge of languages will often be a great asset. In fact, we regard our requirements in two lights—academic qualifications and standards of character or personality.

Academic Requirements

Looking first at the academic qualifications, it is clear that there are no university or other courses in most countries, including the UK, which cater for the requirements of the agricultural chemical industry in any one course. In the United States, there is a tendency for the universities to be in fairly intimate contact with industry, and in that country degree courses are often offered in such subjects as Economic Entomology and Business Administration. One may consider that the relationship between the universities and industry in the United States is perhaps too close, but on the other hand the tendency in the UK is often to lean too far in the other direction. It would seem that a median course between the two extremes could be of benefit to both sides; indeed one can cite Germany as an example of a country in which a realistically close link between the universities and industry, so far as agricultural chemical research is concerned, results in a mutual understanding of aims and interests.

Perhaps the ideal academic background for the agricultural chemical business would consist of a sound basic training in the natural sciences with, say, zoology, botany and chemistry as the subjects involved, followed by a further course in agriculture. What one is looking for, in fact, is a scientifically trained mind which has been broadened by application to a practical subject. It should be added that the actual farming experience usually demanded of agricultural undergraduates is certainly most desirable, for one cannot market agricultural chemicals without going out into the field and, when necessary, using one's hands.

Turning from the background knowledge to the man himself, there are other important requirements. In any progressive industry one is constantly looking for men who will develop steadily throughout their working career to a point where they will become supervisors and, finally, managers; these men will be good ambassadors of the company and, in a word, must be leaders. Recently, Lord Attlee, reviewing the memoirs of Lord Montgomery, paid tribute to the dynamic force of leadership in the following words: 'Techniques and organisation, whether military or civil, are ultimately of secondary importance; the dynamic force is leadership—at all levels—and the leader's power is not know-how but the capacity to command the respect of ordinary men. Leadership . . . depends ultimately on character'. These are surely wise words, for there is little question that the man is more important than his qualifications, even though this may be less significant at the outset of his career than when he has matured.

New British College of Agricultural Engineering

Britain is to have a new National College of Agricultural Engineering which the Ministry of Education is to establish in conjunction with the agricultural engineering industry.

The college will be built close to the National Institute of Agricultural Engineering at Silsoe, Bedfordshire, basically at the expense of the Ministry—the cost is estimated at £250,000—with help from industry in the form of equipment.

Initially the college will accommodate between 60 and 100 students who may come from both home and overseas. Advanced courses leading to a diploma will be provided, and these will include sandwich courses of three years or more, consisting of alternating periods working at the college and in industry.

A board of governors, under the chairmanship of Sir Eric Ashby, Vice-Chancellor of Queen's University, Belfast, and Master-elect of Clare College, Cambridge, has yet to be appointed; it in turn will appoint an architect for the College and a Principal.

A breeding place of Simulium damnosum *in West Africa.*

SIMULIUM FLIES
–pest of man and beast

by **D. J. Lewis,** Sc.D.,

Scientific Staff,

Medical Research Council.

The family Simuliidae contains over 600 species and includes some important pests. Some bite man and several of these transmit human onchocerciasis which is often followed by blindness in certain areas. Some attack animals, causing loss of condition, and several transmit various infections. In some hitherto little-known parts of the world hydro-electric schemes, mining and other developments are bringing more people into contact with these flies and so increasing their importance. There is an extensive literature about Simuliidae; this account deals with some salient features of the subject and a few recent developments.

Man-biting simuliids have received many names in different parts of the world, one of the best known being the North American name, Black Fly; but as this is also used for an aphis, and some simuliids are largely yellow or orange, it is more convenient to use the word simulium, from the name of the principal genus.

Simulium belong to the same group of Diptera as the mosquitoes and midges, but, although small, they are robust flies with large wing muscles in a deep thorax which has given rise to an American name, Buffalo Gnat. They occur in most parts of the world where there are streams or rivers.

Man-biting Pests

Although simulium are widespread important outbreaks of man-biting species are fortunately restricted to certain areas. For instance, the simulium plagues of Canada are almost restricted to the north-east. Although there are 19 British species and it is easy to find countless larvae, even near London, they cause so little annoyance that there is no English name for them. Elsewhere several factors may be involved in producing an outbreak of the kind which becomes sufficiently well known and important to call for control measures to prevent annoyance. Sometimes a strongly man-biting species is present, but there are relatively few of these, probably because the family is

A simulium larva.

The fans with which a simulium larva filters food particles from the surrounding water.

rather small and the breeding habits are such that there are no domestic species.

Man-biting species do not occur in any particular type of country. *S. ochraceum*, for instance, breeds in mountain streams in Mexico, *S. metallicum* in the coastal lowlands of British Honduras, and *S. damnosum* in the desert reaches of the Nile. Some outbreaks are due to species like *S. damnosum*, which bite man in only part of their range. Some species give trouble because they are very numerous. For instance, the spring thaw in north-eastern Canada is followed by the multiplication of the man-biting *S. venustum* and *hirtipes*, and PETERSON and WOLFE (1958) have found that the number of simulium larvae in that region may rise to five million per square metre of river bed. *S. metallicum*, although primarily an animal-biting species, is the commonest man-biter in Guatemala because it is abundant; and *S. griseicolle*, which feeds mainly on birds in the Dongola region of the Sudan Republic, is so numerous at times as to darken the sky, and becomes an almost intolerable pest which hinders agriculture. This is one of several species which annoy people mainly by crawling into their eyes and ears. Some areas, like Jamaica, the 'land of streams', have few or no man-biting simulium for reasons which are not known.

The importance of the type of simulium plague under consideration depends partly on human factors. A few simulium in an important town or tourist resort may give rise to more complaints, and be easier to deal with, than vast numbers of simulium in a remote area where people, perhaps on a low standard of living, learn to put up with them and acquire considerable tolerance to bites as a result of continued attacks over long periods. Some simulium areas remain unknown because people pass quickly through them or because visitors happen to miss a season or year when the flies are common, or simply do not report the prevalence of simulium.

Human Onchocerciasis

Human onchocerciasis occurs in tropical Africa, in a small area in south-western Arabia, and in Central America and Venezuela. It probably reached America in historical times and may still be spreading there. Simulium are numerous in some areas, such as British Honduras, where the disease is unknown, and further epidemiological knowledge is required to show if the infection is likely to spread.

Onchocerciasis is mainly a rural disease, because few towns are built near rapids and those which are can be protected. The causative organism is the nematode worm, *Onchocerca volvulus*, the adults of which live in the human body, the female producing numerous microfilariae (embryos) which occur mainly in the skin where they cause irritation and sometimes structural changes. The eyes may be affected in various ways and much blindness occurs in some simulium areas and has been attributed to the disease.

WADDY (1958) concludes that onchocerciasis is the greatest single cause of blindness in the Northern Territories of Ghana, at least among men, and that it is the main cause of continuing depopulation of river valleys, and he regards it as a major plague in a large part of West Africa.

In some areas, however, the infection seems to do little or no harm and the term 'river-blindness', a rather misleading name for the disease, can cause needless alarm. The cause of the eye lesions and the extent to which they are caused by onchocerciasis is a complicated subject which has recently been reviewed by KERSHAW (1959) and is still under investigation.

The mode of transmission of onchocerciasis was established in 1926 in Sierra Leone, where Blacklock, suspecting simulium because they make a shallow wound, showed that the microfilariae were taken up by *S. damnosum*, passed to its wing muscles, and developed there for some days before moving to the proboscis. Other vectors were discovered in due course, notably *S. neavei* in Africa and *S. ochraceum* in America.

The worms, unlike malaria parasites, do not multiply in the insect host, and their numbers are reduced by the peritrophic membrane* which traps and kills many of them in the mid gut. Relatively few survive to reach the head and possibly infect another person, and even when some of them enter the human body they may not produce the disease. They may be all the same sex, or fail to meet each other, or the host may have some resistance. It follows that a person may perhaps receive many bites before he develops onchocerciasis, and very many before he runs a risk of ocular symptoms which are sometimes associated with massive infection.

Animal Pests

One of the worst simulium pests of domestic animals is *S. columbaczense* which sometimes occurs in immense numbers in Rumania and neighbouring countries and has been known to cause the deaths of thousands of cattle and other domestic animals. *S. griseicolle* kills turkeys and donkeys near the Nile in the northern Sudan, some American simulium cause loss of weight, or even death, in cattle and greatly reduce the egg yield of poultry (LINDQUIST and KNIPLING, 1957), and various species attack animals in other countries.

Biology

Simulium lay their eggs at or just beneath the surface of water. Usually they soon hatch but in eastern Canada some species over-winter as eggs. It has been suggested that one of the African species may pass the dry season in the egg stage but there is little evidence for this. *Australosimulium pestilens*, however, an important pest of cattle in Queensland, has been found by Mackerras to disappear for long periods during which it is thought to survive in the egg stage.

The larva, which is about 5 to 10 mm. long when full grown, has a characteristic shape, with several broad abdominal segments, and lives almost invariably in running water. It produces silk, from very large glands, with which it makes threads to avoid being swept away, and a holdfast which it grips by means of a circle of hooks at the tip of the abdomen. Some species can thus live in torrents where the current exceeds a metre a second. The larvae, however,

* A membrane which is produced after a meal by the gut wall and surrounds the ingested blood.

The posterior ring of hooks with which a larva attaches itself to a silken pad, so avoiding being swept away by the current.

A simulium pupa.

A female simulium (length 3 mm.), its abdomen swollen with blood.

Simulium damnosum—*head with a larva of* Onchocerca volvulus *emerging from it.* (*Photograph taken during dissection.*)

are not always attached like barnacles but sometimes float downstream and reattach themselves elsewhere. Larvae of many species live on any convenient substratum but some attach themselves to definite objects.

Remarkable examples are the larvae of the *Simulium neavei* complex of Africa. *S. neavei* was discovered in 1911, but the whereabouts of its early stages remained a mystery, despite intensive searches by several investigators, for 39 years. Larvae of related species were found attached to may-fly nymphs, and McMahon discovered that those of *S. neavei* habitually fasten themselves to certain fresh-water crabs. Simulium larvae filter drifting food particles from the water by means of fans on the head, composed of delicate comb-like rays, and sometimes browse on the substratum. The pupa lives in a pocket-like cocoon through the opening of which the two gills project downstream.

The adult fly, which is about 2 to 7 mm. long according to the species, emerges in a bubble of gas and quickly flies away. The adults are difficult to study because simulium cannot be reared continuously in captivity, but some of their internal organs change greatly in appearance and, when studied in dissected specimens, provide useful information about the age of the flies and their capacity to transmit disease.

Simulium can fly a long way and their flight is sometimes aided by the wind. Adults are often found 10 miles from their breeding places, and frequently much farther; the Canadian *S. arcticum* has on occasion been carried over 140 miles by the wind. Certain species, like *S. neavei*, are restricted to forest, and others, like *S. damnosum*, occur in forest, savannah or desert.

Female simulium feed on plant sugar and those of many species suck the blood of vertebrates, which provides material for the development of the eggs. Simulium, unlike most mosquitoes, bite out-of-doors by day. Recent studies have shown that, in some species which transmit *Onchocerca*, the parous females (those which have laid eggs and which include the infective individuals) bite mainly at a particular time of day. This implies that the risk of infection with the parasite depends partly on the time at which people are bitten, and that investigations of the infection rate of a particular species must be preceded by a study of the biting times of nulliparous (those which have not laid eggs) and parous females.

Length of life is difficult to assess and varies according to species and climate. In parts of West Africa the egg, larval and pupal stages of *S. damnosum* may last two, six and four days respectively, but the larval period can be shorter, though on the other hand some larvae in temperate regions may live for months. There is evidence that a few adult flies can live more than two months under natural conditions. The method by which some species survive the African dry season has been the subject of much speculation. The adults may remain alive during this period but more investigation is required.

Control

Large scale control of simulium was regarded as impossible until the arrival of DDT enabled one to attack the larvae

with minute concentrations of insecticide. In 1945 Fairchild and Barreda reported the control of some Guatemalan species by applying DDT emulsion to streams, and in 1947 Garnham and McMahon announced the extermination of *S. neavei* in an area near Lake Victoria. The use of DDT in amounts of the order of 0.5 p.p.m. water for 30 minutes became a standard method of control, all breeding places being treated at regular intervals which may be a week or 10 days, or longer, according to the length of larval life. Thus no stream is omitted from which adults could emerge and lay eggs in others.

Sometimes the effect of the larvicide extends only a short distance downstream because the insecticide becomes dissipated in pools. In 1953, however, Fredeen and others in Canada reported the use of an oil solution of DDT which killed larvae for more than 100 miles downstream, and attributed this result to the presence of fine silt which absorbed the insecticide and carried it to the larvae which trapped it with their feeding fans. McMahon and others (1958) have found that in the control of *S. neavei* the DDT concentration must be low enough to maintain a 'tranquil' crab population, otherwise these hosts may leave the water and later return and reinfest it with pupae.

Noel-Buxton (1956) has discussed the use of silt for reducing the required dosage of DDT; Muirhead-Thomson (1957) has studied larvicides in the laboratory with particular reference to the detection of possible resistance; and McMahon and others (1958) have described the virtual eradication of *S. neavei* from Kenya. Wanson and other workers in 1949 announced the control of *S. damnosum* at Leopoldville by spraying DDT from the air to kill adults; Collins and Jamnback (1958) used insecticidal fog in the Adirondacks; and many other workers have studied various aspects of control.

With regard to cost, Crosskey (1958) greatly reduced the *S. damnosum* population in an area of some 1,200 square miles, inhabited by 32,000 people, in Nigeria, at a cost of about £1,000 a year exclusive of salaries. McMahon and others (1958) found that the cost of an extermination campaign in Kenya (exclusive of preliminary survey, salaries and wages of permanent staff) lay between 13s. and 22s. per square mile and was mainly the cost of insecticides.

Simulium have been exterminated in certain isolated areas, and in some of these the flight range of the flies may give rise to anxiety lest the species should return and re-establish itself. In this connection it is interesting to note that Barnley, after controlling *S. damnosum* on the Victoria Nile, found that the death of various insects had allowed algal growth to increase and make the rocks unsuitable for the larvae of *S. damnosum*. In the large areas where extermination is impossible continuous control may be difficult, as shown by Taufflieb (1956) in Mayo Kebbi, French Equatorial Africa, and by Barnley and Prentice (1958) in Uganda; or it may be impracticable owing to the cost of trained staff, houses, roads, transport and other necessities.

As explained above, the nature of onchocerciasis is such that partial or intermittent control may perhaps suffice in some circumstances to prevent serious blindness. Nevertheless, as Crosskey (1958) has pointed out, simulium can sometimes quickly regain its former numbers, and the early successes against these insects must not blind us to the difficulties of widespread control.

Simuliidae are among the insects which have not yet been reported to show resistance to insecticides. There may be several reasons for this: control has been confined to a limited number of species in restricted areas, and in several cases local extermination was rapidly achieved. Owing to the occasional movements of simulium larvae, any of them which are naturally resistant may drift away downstream instead of contributing to the building up of a resistant population in the controlled area. On the other hand, the risk of resistance may be increased by the use of larvicides instead of anti-adult measures (which are usually impracticable because simulium bite and rest out-of-doors), and it is important to keep a look-out for resistance because very few insecticides are yet known to be useful against simulium.

In 1951 Buckley reported the successful control of *S. neavei* by selective bush clearing but this method is only practicable against certain species in limited areas.

Dimethyl phthalate and other repellents provide a useful —and much neglected—means of personal protection against bites.

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Introduction to Seed Dressings

by **M. O. Lane,** *The Shell Petroleum Company.*

The most vulnerable point in the growth of almost any organism is the initial stage and for many crops the germination of the seed is the critical period in the plant's development. It is therefore at this stage that the plant should be protected from seed- and soil-borne disease and from insect attack: seed dressings provide the necessary protection and enable the grower to produce the young plant from which he will eventually take the harvest.

Seed treatment is not a new idea in plant protection; indeed, since medieval times the manuring of seed by dipping it in mixtures of the dung of various farm animals has been reported. Probably the only benefit that could have been derived from such treatment would have been from the action of growth-regulating substances present in animal excreta. Treatments to assist in germination are well known: examples are soaking seed in water before drilling, mechanical decortication or rubbing of sugar beet seed, and soaking of seed in sulphuric acid; these methods are beneficial but are not always reliable for they require either careful handling (acid treatment) or machinery operating to fine limits (decortication).

When life history studies of certain disease organisms affecting cereals were examined, it became obvious that chemical disinfection against seed-borne fungus infection would be beneficial. The earliest fungicidal treatments consisted of liquid formulations of copper compounds or formaldehyde, into which the seeds were dipped, but they so impaired germination and retarded the growth of the young seedlings that the treatments were never favoured. Besides these disadvantages, formaldehyde did not control soil-borne diseases and the need to dry the grain after treatment was an added disadvantage. Arsenic compounds were first tried with some success in Germany in the early 1920s and about the same time mercury seed treatments were also introduced. The latter compounds, containing some 17 per cent. Hg as organic mercury, met with the greater success, but there was a constant risk of phytotoxicity. In 1925 treatment with dry powders containing 3 to 4 per cent. mercury in an organic form was shown to be practicable and from this dust seed dressings were developed. Organo-mercury products gradually became a standard against which further products were tested and over the last 25 years great improvements have been made.

Dual-Purpose Dressings

Today, seed dressings may be fungicidal, insecticidal or dual-purpose, containing both fungicide and insecticide for the control of seed-borne and/or soil-borne pathogens, and for protection of the seeds against soil insect attack. Organo-mercurials are incorporated in these products to give 1 to 2 per cent. of the metal, and other fungicides, such as Thiram or Captan, may be used at levels of 10 to 75 per cent. Such insecticides as lindane or γ-BHC, aldrin. dieldrin and heptachlor are normally formulated in seed dressings at levels of 20 to 75 per cent., depending on the crop to which the product will be applied.

The essential of a good seed dressing is that it should be non-phytotoxic to the germinating seed and that it should have a high activity so that the dosage rate per unit of seed

A cut worm (Agrotis *sp.*)*—a common pest of young cotton in Turkey. Seed treatment with aldrin gives the plants good protection against this soil-inhabiting insect.*

In this wheat field trial the plot seen in the foreground was drilled with seed that had received a mercury dressing only. The seed used to drill the plot behind was treated with a mercury/dieldrin dressing, which controlled wheat bulb fly (Leptohylmyia coarctata *Fall*) *and resulted in a healthy crop.*

is low and the quantity of material that has to adhere to the seed is therefore small. As seed sometimes has to be stored after treatment the dressing should not affect it whilst in storage.

Most research into the protection of seed has been carried out in the temperate zone using cereals—in particular wheat, barley and oats, though all cereal crops should benefit from seed treatment, especially maize and rice. Fungi that attack seeds or are seed-borne are too numerous to list here, but there exists a useful list (3) to which reference can be made.

The ease of application of seed dressings and the comparative freedom from risk of damage, coupled with efficiency and cheapness, ensured a rapid acceptance of the idea of treating seed chemically. H. G. Sanders (4) gives a simple rule for crop husbandry—'that the seed of all cereals (wheat, barley, oats and rye) should be treated with one of the organic mercury dusts; there is no reservation to make and no exception to what should be an unalterable rule'. One might add that treatment with dual-purpose or liquid products can under some conditions be more satisfactory than the use of fungicidal dusts alone.

Liquid Seed Dressings

The advent of volatile liquid formulations came just before the last war, with the development of a liquid organomercury product containing as the active ingredient, methyl mercury dicyandiamide, and known as Panogen; seed can be treated with as little as 200 c.c. per 100 kg. of seed, and although it may not be covered entirely by the material the disease organisms are controlled by the vapour action of the dressing. After liquid treatment with this type of material the seed does not have to be dried since the normal dosage raises the moisture content of the seed by only about 0.2 per cent. Other liquid seed dressings are now available and they all give good control of seed-borne diseases.

Liquid seed dressings have a number of advantages over dust dressings: the toxicant adheres well to the seed and is not lost during transit from the treatment point to the seed drill; there is no dust hazard in the seed dressing plant

A dry seed dressing machine in use.

(although it is advisable to have forced ventilation to avoid excess mercury vapours round the dressing machine); storage of seed for a few days tends to improve the control of the fungal infections; and treated seeds do not cause stoppages in seed drills. In addition, liquid seed treaters tend to be easier to operate than dust treaters, though unless the farmer has bought a machine specifically for liquid treatment he will be unable to use a liquid dressing himself, whereas with dust treatments a home-made drum treater can be used.

Slurries

Besides the normal use of liquid and solid formulations, the latter can also be applied in the form of a slurry (the American 'quick wet' method). Slurry treatments involve the use of suspensible powder, to which a small quantity of liquid, usually water, is added; this helps to increase the loading of the seed with chemical. Although slurries are effective in giving a good coverage of dressing to the seed, they have the disadvantage that the seed has to be dried after treatment, and are not very widely used outside the USA.

An important factor when treating seed which is often forgotten is the quality of the seed before treatment. A poor seed sample of low initial germination or a sample containing badly damaged seeds is unlikely to be improved by seed treatment, in fact badly cracked or chipped seeds are liable to suffer severe phytotoxicity when treated with mercury products, as the embryo is likely to be exposed to the chemical. In any case, seed, of what ever quality, should never be over-treated with dressing, or reduced germination or abnormal growth may result.

In the future, we may see the increased use of antibiotics for seed treatment and an expansion in the use of systemic pesticides which will give protection not only to the seed but also to the young plant. Control of internal parasites of seeds cannot be satisfactorily carried out with conventional fungicides because they are unable to penetrate the seed to the point of infection. However, two antibiotics, rimocidin and pimaricin, have been successfully used by DEKKER (2) in experiments using pea seeds infected with *Ascochyta pisi* Lib. (leaf or pod spot).

It has been reported (*Farm Chemicals* **120,** 9, 44 [9th September, 1957]) that the systemic insecticide, Thimet, has been used with success in some areas for seed treatments of cotton, protecting the plants against insects for up to ten weeks from germination. Thimet has also been used on sugar beet and alfalfa.

Dust treatments of all types are well established but liquid products may well come into prominence. In areas with under-developed agricultural systems, and a shortage of capital for the purchase of spraying machinery and large quantities of agricultural chemicals, seed dressings will help to raise crop yields at low expense. Crop protection authorities are well aware of the dangers of seed-borne diseases (1) and we may well find in the future that legislation is introduced to improve the quality of seed available to world markets.

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NEW SPRAYERS SHOWN IN LONDON

by **G. R. G. C. Tickler,** *The Shell Petroleum Company.*

The new Wasp tractor-mounted mist blower introduced by Drake & Fletcher Ltd.

Every year, British machinery manufacturers introduce new machines and show old models in new dress at the Smithfield Show. Last December the majority of United Kingdom spraying equipment manufacturers appeared to have decided that the time had arrived for consolidation rather than expansion, since few firms introduced new models. This report gives some indication of the new spraying equipment which has been recently introduced, but does not claim to be comprehensive. Prices are given for comparison; they are for home sales, since many manufacturers only quote export prices on request.

Drake and Fletcher Ltd. exhibited the new tractor-mounted 'Wasp' mist blower (£475) which has been designed specifically for use on hops and fruit. This machine has several interesting features: not only has it been fitted with the first commercial version of the experimental atomiser nozzle developed by the National Institute of Agricultural Engineering, but it also has a 60-gal. moulded fibre-glass tank. Concentrates pass rapidly from this jet-agitated tank, through four inlets into the centre of the airblast generated by the forward curved multivane centrifugal fan, which has an output of 4,000 cu. ft. per min. The droplets are blown at 200 m.p.h. through each of the four atomiser nozzle outlets. The complete atomiser unit, which can be easily raised and lowered by turning two small hand-wheels, is composed of four standard 3 in. diam.

Kent Engineering & Foundry Ltd. have recently made this Powermist sprayer (for low, medium and high volume work) available for export.

E. Allman & Company's Rapid—a new sprayer for the small grower.

outlets. Each outlet is manually adjusted, enabling full directional control to be obtained. Although it is claimed that the 'Wasp' will spray accurately at rates of 5-50 gal. per acre, the manufacturers believe that higher application rates may be obtainable. The 16 g.p.m. turbine pump has a stainless steel rotor.

Following its use in Denmark for the low volume treatment of fruit trees, the 'Dorman-Bulow Orchard Mist-sprayer' is now being manufactured in the United Kingdom by the Dorman Sprayer Co. Ltd. This machine, it is stated, will apply accurately 2½-50 gal. per acre; it is fitted with a high capacity piston pump. Although the ideal pressure for mist spraying with this machine has been found to be 70 p.s.i., pressures of 350 p.s.i. are used when hand lances are fitted to the distribution point. Because lime-sulphur is widely sprayed on fruit trees in the United Kingdom, the 'Dorman-Bulow' has been fitted with a paddle agitator not employed on the Danish model. The high volume (5,600 c.f.m.) high speed (11,000 ft. per min.) fan is fitted with a split casing and four outlet points, which can easily be adjusted to enable either single-sided or double-sided spraying to be practised. This machine costs £360, weighs 6 cwt. when fully loaded and is only 4 ft. 3 in. high.

The Dorman Sprayer Co. have also broadened their existing range of equipment by the introduction of several new tractor-mounted sprayers. Additions to the 'Standard' range were the 80-gal. and 100-gal. models, both equipped with 21 ft. boom, 12 g.p.m. pump and galvanised tank, and costing respectively £115 and £130. These models, and also the new 100-gal. 'Super' and the 80-gal. 'Utility' can all be equipped with Dorman non-drift nozzles. These are hollow cone nozzles, which have been introduced to enable ultra-low pressure spraying, at 10-15 p.s.i., to be carried out, thus reducing or eliminating wind drift and consequent spray drift damage.

The Midox Co. showed for the first time in the United Kingdom two Danish R.S.M. sprayers. The mounted R.S.M. model (£395-£495), suitable for both large and small growers, has a 65-gal. tank and can be fitted with four, eight or 10 nozzles to give either single or double-sided spraying. A working pressure of 400 p.s.i. is obtained by using either a single cylinder pump delivering 5 g.p.m. or a twin-cylinder pump delivering 10 g.p.m. The 'Popular' petrol or electrically powered model has been developed for the high volume spraying of market gardens and greenhouses. Both the wheel-mounted and skid-mounted models are equipped with 16 or 25 A.G. chemically resistant steel tanks. The single cylinder piston pump will apply 3 A.G. per minute at any pressure up to 350 p.s.i. through either hand lances or a spray boom.

E. Allman and Co. Ltd. have extended their range of equipment by making the 60-gal. 'Plantector' field sprayer available for use on both the Austin Gipsy and the Land Rover. Costing £92 10s., this model is equipped with a patented control system—the 'Genimec'—which incorporates boom selection, pressure regulation, hydraulic agitation, and automatic non-drip suck-back, which the makers state can be easily controlled by the operator. The ¾-in. 'Rollervane' pump will operate at pressures of up to 350 p.s.i. Application rates of 5-75 gal. per acre at speeds of 2-4 m.p.h. can be obtained by fitting nozzles of varying sizes. The addition of both 'under' and 'over' leaf equipment or a hand lance enables fruit trees, hedgerows, cattle and buildings to be sprayed.

Specifically for the small grower, Allman have introduced the 'Rapid', a single-wheeled sprayer costing, for a single unit, £39 19s. 6d. It is 6 ft. long, has an overall height of 2½ ft., weighs 60 lb. unladen and is equipped with a 6-gal. tank. The two brass pumps operate at a pressure of 20-60 p.s.i. to enable an output of 20-50 gal. per acre to be obtained.

Although the tractor-mounted 'Powermist' sprayer, manufactured by Kent Engineering and Foundry Ltd., has been available for the home market since early in 1957, it has only recently become available for export. Costing £595, this powerful unit is suitable for the low, medium or high volume spraying of fruit trees and hops and is operated from the power take-off shaft of a medium sized tractor. A 30 g.p.m. pump is mounted on the enclosed oil bath gear box. The 200-gal. tank, which is trailed behind the power unit, has been specially designed with curved edges to ensure an efficient swirl of liquid by the built-in jet agitator.

CROP PROTECTION EQUIPMENT IN JAPAN

This knapsack power duster can be converted to a mist blower by fitting a liquid tank in place of the dust hopper and changing the nozzles.

The increased use of agricultural chemicals in Japan in recent years has resulted in a very marked expansion in domestic production of spraying and dusting machinery, as the figures in the accompanying table show.

While simple hand-operated equipment is used by many vegetable and tobacco growers, and in terraced fields (irrigated and non-irrigated) where the cultivated area is small, the use of powered machines is gaining popularity, especially where collective pest control is practised in irrigated rice; such sprayers are also used on the plains.

In orchards, collective pest control or a static spray system is fairly common. The latter involves the installation of stationary engines which are connected to permanent distribution pipes tapped at intervals for hoses and land lances. Fruit trees are not commonly dusted in Japan.

Low volume spraying machines have not so far proved popular in Japan as their size and weight tend to make them unsuitable for spraying crops growing in irrigated fields or orchards planted on hillsides. On the other hand, many different types of mist sprayer, ranging from easily portable small knapsack machines to large tractor-drawn models, are being manufactured; most of them are designed for high volume application.

A new development is the introduction of a knapsack power duster which can be converted to a mist blower by substituting a liquid tank for the dust hopper and changing the nozzles. Although knapsack dusters are generally powered by a 1.2-1.5 h.p. engine, mounted on the machine, some of the newer models are operated by an electric motor working from a wet battery, but at present these tend not to be sufficiently powerful to provide adequate wind velocity and volume.

Injection equipment for applying soil fumigants is being developed in Japan; a hand-operated injector is in production and a metering injector which can be fitted to two-wheel tractors is being tested.

For the control of insects in forests, aerial spraying and dusting by helicopter is now being employed and it is thought that this method is also likely to gain popularity for the control of flies and mosquitos in towns. The application of pesticides by helicopter to citrus orchards in steep hillsides is also being studied but the application of chemicals to rice paddies has yet to be seriously considered.

These notes have been compiled from information supplied by the Department of Entomology and Phytopathology, National Institute of Agricultural Sciences, Tokyo.

Japanese Production and Sales of Spraying and Dusting Machinery

Type		1950	1951	1952	1953	1954	1955	1956	1957 (Oct.)
Power Sprayer	*Manufacture*	8,855	7,682	11,151	12,876	25,259	25,969	32,664	28,635
	Sales	8,557	7,824	11,140	12,710	23,791	25,659	32,232	—
Power Duster	*Manufacture*	1,292	2,140	2,112	7,485	23,661	14,977	15,447	17,977
	Sales	1,320	2,272	1,930	7,863	22,526	16,567	15,677	—
Hand Sprayer	*Manufacture*	163,331	126,949	159,695	214,173	277,140	224,313	335,044	267,898
	Sales	185,561	110,734	156,191	226,323	254,550	236,330	332,369	—
Hand Duster	*Manufacture*	95,663	60,475	166,874	196,458	254,825	218,193	188,689	221,284
	Sales	103,419	61,841	147,407	202,945	243,804	201,839	199,943	—

Books

MODERN CITRUS GROWING

Citrus Fruits. H. H. Hume. Macmillan, New York. $10.50 or 73s. 6d.

Dr. Hume has long been recognised as one of the United States' leading agricultural and horticultural workers. A world-wide authority on citrus, he has already published *Citrus Fruits and Their Culture* (1904) and *The Cultivation of Citrus Fruits* (1926). This informative revised publication of his last book deserves to be carefully studied by all concerned with citrus growing.

Although *Citrus Fruits* is slightly larger in format than its predecessors, it contains fewer pages and is more attractively presented. The large number of illustrations—some of them excellent—will be appreciated by all citrus growers, since they have been carefully chosen to illustrate important points mentioned in the text.

The complexity and vastness of the field covered by the term 'citrus culture' has resulted in Dr. Hume touching on many points only too briefly. Whereas one may feel that too much space has been devoted to fumigation, one would like to have seen more information on the increasing use of nucellar strains, and the rising importance of insecticidal oil sprays. However, whether Dr. Hume is discussing the origin of citrus fruits or the various methods of packaging and handling, he writes fluently, succinctly and authoritatively.

From their origination in Cochin citrus fruits have spread throughout the world to all suitable areas. Their commercial success in the United States has been largely due to the establishment of co-operative marketing organisations, which —working in conjunction with the United States Department of Agriculture—have found new markets for citrus fruits, and have developed new varieties and species suitable for a wide range of climatic and environmental conditions. These new varieties have added confusion to the complex but orderly botanical classification of the citrus fruits compiled by Dr. W. T. Swingle, which indicates that the one thousand species of the family Rutaceae occur in three genera—*Poncirus*, *Fortunella* and *Citrus*.

Continual attempts are being made to extend the range of citrus fruits into cold and dry regions by the use of such hitherto commercially undesirable species as the Australian desert Kumquat and the wood apple of India and Ceylon.

The practical grower is likely to be but briefly interested in the judging of citrus fruits, on which an informative chapter is included, but he will be keen to learn as much as possible about propagation methods. Although propagation of citrus fruits is now mainly carried out in the United States by both budding and grafting on to stocks, the use of seedlings and cuttings is still recommended under certain circumstances.

The location of a citrus grove provides many problems, but the author advises 'Find water, then find a piece of ground to put it on'. Without an adequate supply of water, it is most unwise to attempt the cultivation of citrus fruits, since weakened trees are very susceptible to both pest and disease attacks. Although water will be needed throughout the year, it is particularly required during the blooming and fruit setting periods. Any shortages occurring at this time must be made up by irrigation, preferably by the check system; under careful management, the check system would appear to be foolproof and infinitely preferable to irrigation by either flooding or the furrow system.

The commercial success of the grove is also dependent on correct fertilising and careful cultivations. Both young and old trees must receive an adequate supply of plant nutrients and be maintained in a healthy condition, since it is always easier to maintain trees in good condition than to improve poor trees. By favouring 'no cultivation' methods, the writer emphasises that clean cultivation should definitely not be practised, since barren soil rapidly dries out to lose organic matter and plant nutrients. This decline in both fertility and water-holding capacity is prevented by the growing of cover crops.

The several excellent chapters on frost considerations, pests and diseases, spraying and fumigation should be carefully studied by all citrus growers. The writer emphasises that, while frost damage can be minimised by employing protective measures such as trunk-wrapping, earth-banking, windbreaks or fires, the resistance of trees to cold temperatures is dependent on their healthiness, state of dormancy and the presence of insects. Growth should never be encouraged during cold spells by applying too much nitrogen or by excessively early spring cultivations. The careful choice of stocks may reduce frost damage, since both rough lemon and sweet orange stocks are considerably less frost hardy than trifoliate orange stocks.

While the informative chapters on pests and diseases and their control are particularly to be recommended, it is surprising to find no mention of the citrus nematode, *Tylenchus semipenetrans*, which is an important pest in most citrus growing areas.

Biological control methods should never be neglected and, as has recently been shown, they can be effectively employed to control many citrus pests. The Australian ladybeetle, *Rodolia cardinalis*, has successfully controlled the cottony cushion scale, *Icerya purchasi* Maskell, while aschergonia fungi are predators on various whitefly species.

Citrus growers throughout the world will be grateful to Dr. Hume for this book and will hope that a worthy successor to it will eventually be written by an equally eminent authority.— G. R. G. C. TICKLER.

MANUAL OF WEED CONTROL

Weed Control Handbook. Issued by the BRITISH WEED CONTROL COUNCIL. Blackwell Scientific Publications, Oxford. 12s. 6d.

In the past, the British Weed Control Council, in order to keep pace with the rapidly developing practice of chemical weed control, have found it necessary to issue the *Weed Control Handbook* annually. This publication has now been put on a more permanent basis and the result is a well-presented and informative book which fulfils a long standing requirement and gives not only recommendations but a great fund of information on most aspects of chemical weed control. Although the crops, weeds and problems discussed are primarily those of a temperate zone, and the UK in particular, this book will prove of immense value to anyone interested in the practical and technical aspects of weed control. A unique feature of this publication is that the information and recommendations it contains are the result of collaboration between the principal commercial and official organisations concerned with weed control in the UK.

The book is divided into five Parts, the first of which is introductory and deals with the terminology and classification of herbicides plus a brief note on formulations, concluding with short and concise notes on the herbicides used in Great Britain. In past editions of the handbook, herbicides have been classified according to both mode of action and chemical type. In the new book, however, the classification has been confined to mode of action, and the chemical weedkillers have been classified as selective and non-selective—the former being subdivided into contact, translocated and residual herbicides. The whole effect is to give a clear and detailed introduction to a very complex subject.

Part II of *Weed Control* is entitled 'Recommendations and Information concerning the Use of Herbicides' and, as well as being the largest part, it will be the most important as far as the practical man is concerned. The authors have divided this Part into seven chapters which cover agriculture, horticulture, forest nurseries, lawns and sports turf, special weed problems, non-selective weed control and pre-harvest dessication.

The chapter devoted to agriculture describes in detail firstly the problems and techniques of weed control in cereals, arable crops and grassland, and then goes on to outline in tables the susceptibility to the commoner herbicides of over 200 annual and perennial weeds. The control of the more important of these weeds is discussed in detail.

The horticulturalist will find much interesting information in the chapter on weed problems in horticultural crops. This, apart from giving recommendations for the use of selective herbicides in vegetables, fruit, flowers and ornamentals, discusses new trends in selective weed control.

The remaining chapters in Part II give a similarly wide coverage to their respective subjects together with lists of the commonly occurring weeds and their susceptibilities to the weedkillers most widely used in these situations.

Under the heading, 'The Application of Herbicides' the authors have split Part III into two chapters, the first of which is devoted to the actual mechanics of application and the other to legal aspects and insurance. The performance, advantages and disadvantages of the different types of machines used in applying herbicides are fully discussed. The section devoted to spraying procedure supplies all the information required for calculating spraying rates with a wide variety of formulations and machinery. There is a novel and interesting section on the compatibility of herbicides with each other and with insecticides and nutrients. This information has been summarised in a simple table.

Part IV outlines the legal position concerning noxious weeds and describes the seed certification schemes existing in the United Kingdom.

'Approved and New Herbicides' is the title given to Part V and to many readers the notes on new herbicides will prove to be some of the most interesting reading in this book.

Finally, there are three appendices which cover respectively a glossary of terms, a list of common names and chemical abbreviations covering over 80 chemical herbicides, and the properties of herbicides. The latter tabulates the chemical and physical properties of 56 weedkillers.

Not the least important aspect of this book is the index,

which is comprehensive and clear and allows quick reference to information on chemicals, weeds and crops alike.

This authoritative, up-to-date and detailed reference book can be strongly recommended to the practical man and those engaged in advisory work. In addition it will provide an invaluable introduction for anyone new to the subject.— I. A. H. SYME.

Diseases of Tobacco. G. B. LUCAS. The Scarecrow Press Inc., New York. $10.

This book is a major work on tobacco diseases and one of the best in its field. In a concise form it contains a wealth of information on diseases caused by nematodes, fungi, bacteria and viruses. It describes, besides a large number of fungus and virus diseases, diseases caused by nematodes, parasitic plants, and nutritional disorders. The chapters on specific diseases all follow a main pattern: importance and distribution, symptoms and signs, etiology, host-parasite relations, influence of environmental factors and control measures. With regard to the latter, much attention has been paid to disease-resistant varieties and cropping sequences in relation to disease control. It is also pointed out that hygiene is still the keynote to many disease problems.

The section on nematode diseases is particularly valuable, and the attention paid to nematode species other than those belonging to the genus *Meloidogyne* is enlightening, since not long ago 'rootknot' was considered to be the main, if not the only problem, in tobacco. The importance of nematode/fungus complexes in the soil, although not fully understood, is also cited in a few instances. Wind, incidentally, might well have been mentioned as a factor in the distribution of nematodes, especially on sandy soils.

Far more information is available on fungus diseases which occur in the USA than elsewhere. Even bearing in mind that this is an American book, this is surely a reflection on the poor research facilities and the limited plant pathology staffs in many tropical countries.

It is perhaps of interest that, in the reviewer's experience, *Phytophthora* has not been a problem in Sumatra since twice-weekly seedbed spraying with copper fungicides was introduced; these treatments also reduce the incidence of *Pythium* and *Cercospora*. Against the latter disease mixtures of ferric dithiocarbonate and copper oxide have been found more effective than either compound alone. Granville wilt remains one of the biggest problems of tobacco growers in many countries: while the use of soil fumigants can bring about an appreciable reduction in the incidence of this disease, crop rotation seems, for the present, the most satisfactory control method, even though varieties of flue-cured tobacco resistant to the disease have been developed.

Again, in the reviewer's own experience, virus diseases lose much of their importance if insecticides are employed as a routine measure in field tobacco. Leaf curl ('krupuk') transmitted by *Bemisia*, occurs very rarely nowadays in Sumatra tobacco, and it looks as if even the number of mosaic infestation centres are reduced by the application of insecticides, although no proved insect vectors are known. It is, of course, true that if such a centre exists, spread by mechanical means may still affect large patches of tobacco, and frequent washing of hands and tools with soap and water is still recommended.

The only part of the book which is disappointing is that on nutritional diseases, which consists only of descriptions of deficiency and toxicity symptoms. No mention is made of sulphur toxicity, which is as important as chlorine toxicity in its effect on tobacco quality; nor are the underlying causes of deficiency and toxicity symptoms, the effect of the soil pH, or K/Na and Ca/Mg inter-relationships mentioned.

Chemical disease control measures, apart from soil fumigation, are only summarily mentioned, and some of the newer chemicals have not been dealt with at all; information on residues, and on the effect of chemicals on flavour, fire-holding capacity and fermentation or curing would have been most welcome.

The literature, although not complete, is very fully covered up to 1957 and contains many non-American references. As such, the book is a good starting point for a more profound study of particular tobacco diseases. It will be invaluable to plant pathologists in general and tobacco research workers in particular, although it may be too technically written for non-biologists. The drawings are excellent, as are the black and white photographs.— A. M. H. SANGER.

Land: The 1958 Yearbook of Agriculture. Edited by A. STEFFERUD. The United States Department of Agriculture, Washington, D.C. $2.25.

The subject of the 1958 *Yearbook of Agriculture* is admirably summed up in the following quotation from the first chapter:

> 'Land is many things to many persons—to the farmer, livelihood; to the townsman, space or a place to build his house; to the child, a playground; to the poet, a theme; to the patriot, a symbol.
>
> To the economist, land is the soil under his feet, the materials in that soil, the slope that determines the ease of cultivation, the rain and sunlight that plants need.
>
> To him, land also is the bays and inlets along the coasts; the fall of the streams, which permits the hydraulic generation of electricity; the rivers on which are carried grain and industrial products to the seaports.
>
> It is the deposits of iron ore in Minnesota, the coal in West Virginia, the oil in Texas.
>
> It is the soil and climate that make timber in the Pacific Northwest, corn in Iowa and Illinois, wheat in the Great Plains, cotton in the South, citrus fruits in Florida, pastures in Wisconsin and New York.
>
> Land, in the economic sense, is our entire natural environment—all the forces or the opportunities that exist independently of man's activity'.

Subsequent chapters detail the land resources of the United States and discuss the ways in which these resources have been used since the arrival of the first settlers. There are contributions on land ownership and tenure, and on many aspects of the present use and management of public and private lands.

Anyone wishing to study the agriculture of the United States will find in this book a wealth of interesting material. Different authors have written accounts of the types of farming carried on in the main regions, and have followed the changes in farming practices brought about by alterations in the economic climate and by man's misuse of the land in the past.

To the practical agriculturalist outside the United States, this yearbook is of less direct value than earlier ones in the series dealing with topics which apply less specifically to the United States. Nevertheless, it contains many thoughts and ideas which could be applied elsewhere, particularly in those sections dealing with such aspects as the financing of farming and the purchase of farm land, the irrigation of humid as well as of arid areas, the proper control of watersheds and of water and the causes of the sprawling urban development occurring in so many countries.— R. A. BERENDT.

Small part of a miracle

Pink snowflakes, floating from the wind-stirred cherry tree: willow fingers wet with spring rains noisy on bright umbrellas. A landscape washed with soft and glowing colour, of new leaf and flower and bud. Spring in Japan—a time for loveliness. And for the farmer, worry. For in the awakening world, pests both below and above soil are also awakening.

In Japan, rocky and mountainous and desperately short of arable land, some 90 million people are crammed into only 142,800 square miles—of which under 20% will bear crops. Yet, despite often violent climatic conditions and a not naturally very fertile soil, Japanese farmers manage, by some of the most intensive cultivation in the world, to provide from 80 to 85% of the nation's food supply—a miracle of production calling for immense efforts of care and attention *and protection against loss.* For every ounce of food is priceless.

Among pests which attack the vegetable crops on the terraced hillsides, the onion fly (*Hylemyia antiqua Meig.*)—which also attacks leeks and shallots—is of considerable importance, not only because of the severe damage it causes but because of its rapid breeding cycle. Eggs laid on Sunday will by Wednesday be larvæ which will feed, destructively, on the crop for three weeks before pupating. Seventeen days later a new generation of adult flies will be on the wing. To control this prolific pest, known in many countries, farmers in Japan are now employing the same sure remedies as those who crop vaster fields in other lands: aldrin and dieldrin, the powerful insecticides developed by Shell. Aldrin, either as dust or spray, broadcast before planting at 2-3 lbs. per acre (2·2-3·3 kg. per hectare) or used as a row treatment during growth using ½-1 lb. per acre (0·6-1 kg. per hectare), will give effective and lasting control. And not only of the ubiquitous onion fly, but of many other threatening pests of the soil. In any language, aldrin means destruction—to those which themselves seek to destroy.

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